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Contribution from the

Western Washington Experiment Station

The Blackberry Mite and Its Control

(*Eriophyes essigi* Hassan)

by

Arthur J. Hanson

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THE BLACKBERRY MITE AND ITS CONTROL

(*Eriophyes essigi* Hassan)

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This publication presents the results thus far obtained in a study of the life history and control of the blackberry mite, investigations which have been conducted on the planting of Oregon Evergreen blackberries at the Western Washington Experiment Station at Puyallup. Approximately 65 per cent of the berries in this planting in 1931 failed to ripen because of the blackberry mite.

Identity of the Mite

When the mite first attracted attention in California, it was determined as *Eriophyes gracilis*, which injures raspberry foliage in Europe. In 1928, however, Hassan (4) described the California mite as a new species, *Eriophyes essigi*.

Occurrence in Washington

The blackberry mite was first observed in Washington in September, 1930, on the experiment station planting at Puyallup. During September and October, 1930, specimens were sent to the Department of Entomology from Bellevue, Mount Vernon, and Bellingham, indicating a rather wide distribution in western Washington.

The exact means of introduction of the blackberry mite into Washington is uncertain. There are some indications that it was brought in with berry crates from an Oregon cannery. Another possible method of introduction is in the movement of nursery stock. The mite could easily remain unnoticed in the buds of the plant.

When first noted in California in 1921, the mites were observed on the Himalaya variety. Other varieties of blackberries, even when grown in close proximity to the infested Himalayas, remained unaffected.

In 1930, L. M. Hatch, president of the Puyallup & Sumner Fruit Growers Association, estimated that 30 per cent of the berries harvested in Washington and 65 per cent harvested in Oregon were from

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uncultivated plants. It is possible that the mite may be a limiting factor with these wild berries. The process of distribution in the wild plants may be slow, depending on the seriousness and the adaptability of the mites to the region. In its second year under observation in the state, the mite population was not so large as the first year, although a larger number of plantings were affected.

Nature of the Injury

While in the berry, the blackberry mite feeds near the base of the drupelets around the core as indicated in Figure 4. This causes a change in color from the normal maroon of the unaffected fruit to a more brilliant red. (See Figure 1.) The number of mites living in a single red berry during late September varies from less than 100 to as many as 683, according to records made during these investigations. No doubt as many as a thousand may be present on occasion.

The number of mites necessary to cause a berry to remain red is uncertain. Some affected berries turn black with mites in them; others may have one to several red drupelets. This condition ranges from a single black drupelet on a red berry to a blackberry with a single red drupelet. Some berries, entirely black when harvested, change to reddish-black after standing in the crate a few hours. Apparently the length of time spent within the berry has an effect.

In California and in England many infested Himalaya berries never get beyond the green stage, whereas in Washington all the berries reach the red stage, and the color transformation of the red fruit is the most noticeable characteristic of infested fruits. Berries that set late in the season continue to develop until they reach the red stage, when development ceases. Individual drupelets of red berries dissected in October often show a slight blister-like appearance on the side where the mites have been feeding.

Extent of Injury

The fruit injury by the blackberry mite is limited mainly to the late maturing varieties, the Himalaya and Oregon Evergreen. In addition, however, the mite has been observed in cane buds of the Texas and Layton varieties, also on Cuthbert raspberry, and loganberry. Late varieties are subject to loss primarily because the mites are late in migrating from the scales of the winter cane bud to the fruit; again the mite population is not sufficiently large to cause a general "red-berry" condition on early maturing bush blackberries. Affected fruit of the Texas variety occurred only on a few berries late in August after the main crop had been harvested.

Distribution in North America

In California the blackberry mite is most serious along the coastal areas of the central and northern portions, apparently being more

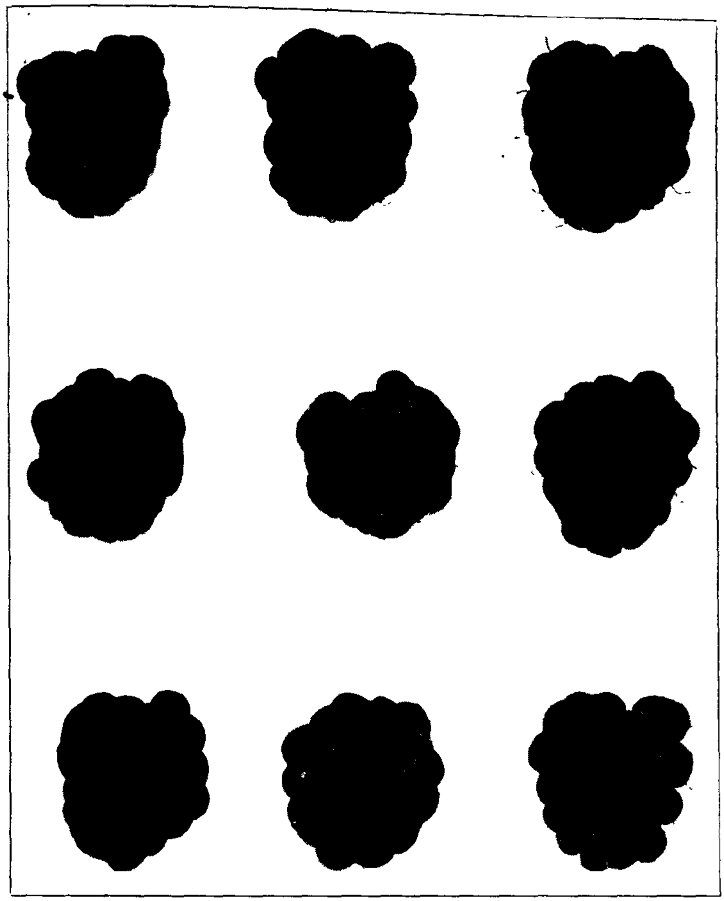

Figure 1. Oregon Evergreen Blackberries, showing typical color of fruit affected by the blackberry mite Normal ripe berries on right.

adapted to the cooler region along the coast. The present distribution in the United States is the coastal area extending from Mexico on the south to Bellingham, Washington, near the Canadian line, on the north. A large proportion of the blackberry districts in Washington and Oregon, however, are yet unaffected by the blackberry mite

In England, Massee (5) reports the mite distributed over the entire country, serious wherever environmental factors are favorable. The mite apparently is European in origin, remaining undescribed until its establishment in California. This is likely, since Darrow (1) states that the Evergreen and Himalaya are horticultural varieties of European blackberries. These two varieties were introduced into the Northwest prior to 1860 and are well adapted to the region, especially west of the Cascade Mountains where they succeed both in the wild and cultivated state.

Description

The blackberry mite belongs with a group of plant feeding mites, so small that they cannot be observed by the unaided eye. At harvest time their presence can easily be determined by the affected fruit. At other periods of the year however, some difficulty is experienced in locating the mite and determining infestations. The mites vary in length from approximately .125 mm. to .156 mm. The body is long and tapers; vermiform in general outline, as indicated in Figure 2. It is divided into two regions: cephalo-thorax and abdomen. The cephalo-thoracic region bears the mouth parts, a pair of needle-like organs called chelicerae, used in puncturing plant tissues, and also two pairs of legs.

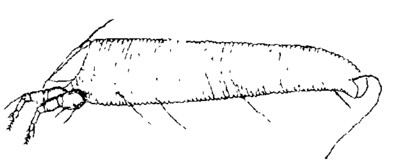

Figure 2. The blackberry mite Eriophyes essigi **Hassan. Enlarged 300 times.**

The abdomen is divided into 80 divisions by striae which encircle the entire body. On the abdomen there are three pairs of ventral bristles, one pair of lateral bristles, and one pair of dorsal bristles. Usually the mite is white, although some winter forms vary from yellow to amber. The male is slightly smaller than the female. The dull white eggs are spherical in general outline and approximately .005 mm. in diameter and are deposited between the bud scales and between the drupelets of the berries.

Life History

In fall the mites have no definite migratory period from the berries to the cane buds. Red berries form a desirable location in which they remain until decomposition takes place. As soon as the berries decay, the mites leave the fruit. The decline of the berry is retarded by the feeding, with some berries retaining a faded-out red color until midwinter. Mites have been observed in these old berries on January 13.

At all periods of the year the mites may be located in the buds or under old bud scales of the previous winter cane buds. (See Figure 4.) Early in fall the majority of the mites on the new canes are found in the axis of the cane buds and the compound leaf rather than inside the cane bud itself. As the winter months advance, more are found inside the bud between the bud scales. The mortality of the mites during the period from summer to the following spring is very high.

During the summer there may be, in a heavily infested field, an average of several hundred mites per berry. In such a field, when 100 buds were examined the following March, there was an average of 9.8 mites per bud, the range observed being from none to 79.

A number of factors act to reduce the overwintering population. Many mites never reach the cane buds from the berries; others are destroyed by the predacious mite feeding upon them; unfavorable climatic conditions may be responsible for further reduction. Low temperatures, however, do not appear to affect the mites within the berries. Berries on plants in the field were subjected to a temperature of 21 degrees F., yet when examined November 21, 1931, contained mites, none of which seemed to have been affected adversely.

The mature adult mites that go through the winter start reproduction early in spring. The first eggs were observed March 8 at Puyallup, when four were located beneath a single bud scale. March 19 the development of the first brood was well under way, many eggs being observed on that date. On one occasion 40 eggs were seen under one bud scale, while only three adults were present.

The mite population is built up by continual increase which starts in March, reaches a peak during September, and decreases during the fall and winter. The last eggs observed were on December 20, when three eggs were located.

The number of generations during the year is indefinite, because of a continual overlapping of eggs and immature stages. Increase in mite population is rapid, since it is a short time between the egg and adult stage. The length of time from the egg to the adult stage has not been determined, but it is improbable that it is longer than that of the citrus rust mite of Florida, from 8 to 11 days.

Massee (5) reports that in England the mite, after hibernating in the bud, migrates to the developing foliage, reproduction first taking place on the leaves and among the leaf hairs. As the flower buds form there is a migration from the leaf to the flower buds and the flowers.

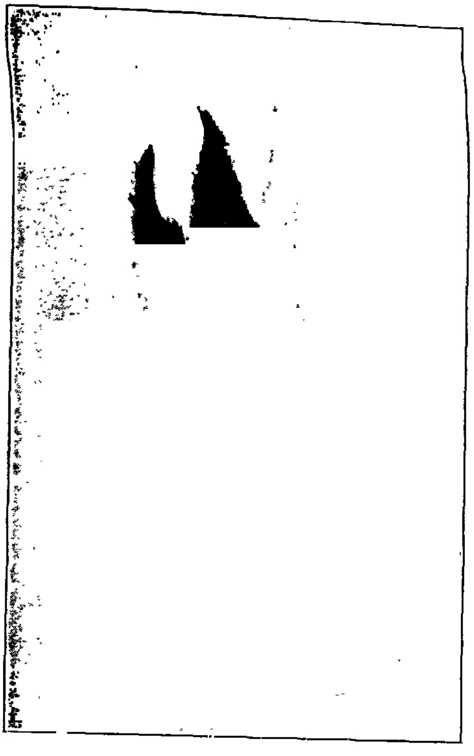

Figure 3. Bud scale showing mites on the inner portion of the scale—April 2, 1932.

In California the migration is directly from the cane buds to the developing flowers. In Washington this movement does not take place until later in the year, when the mites migrate from the bud scales to the green berries. Not all mites leave the scales of the old winter cane buds; some few remain until the following fall. Those which do migrate go from the scales of the old winter cane buds to the green berries. In 92 green closed fruit buds examined in untreated plots at Puyallup between June 9 and July 1, not a single mite was

observed. Again in 39 open flowers examined from June 23 to June 30 there was but one mite. From the same material there was a total of 1499 mites under the scales of the 18 old cane winter buds, or an average of 83.3 mites.

On the blackberry planting at the Western Washington Experiment Station, both in 1931 and 1932, 35 per cent of berries were harvested under heavy infestation. The remaining 60 to 65 per cent turned partly red or entirely red. In the check plot in this planting in 1932, where no spray treatment was applied, only 35 per cent of a crop was harvested. Berries that set late in the season are severely affected by this mite wherever it has become evident in the state.

It appears that mites are carried from row to row mainly by air currents when the infestation is spread over a field. When migrating

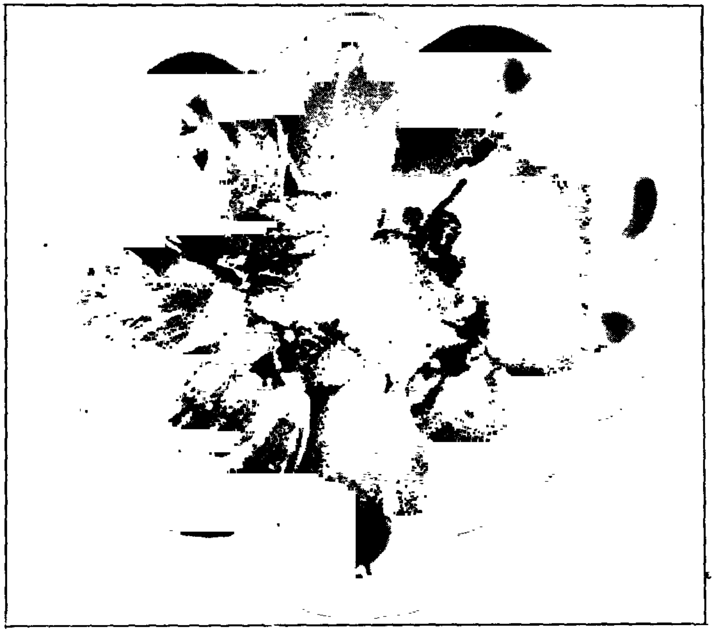

Figure 4. The mites are located in the fruit between the druplets and around the core.

from the buds, they may be easily picked up and carried by the wind to the adjoining rows. This was illustrated by the unsprayed check plots in the spraying tests conducted at Puyallup last season. A buffer row was sprayed three times in order to insure a control. At harvest

time only those berries adjoining the check plots were seriously infested. This row was east of the check, and in this whole plot the east side of the row was more severely affected than the west side.

Natural Enemy

The predacious mite, *Sejus pomi* Parrott, an effective natural enemy of the blackberry mite, is often observed between the drupelets of the berry as well as on the leaves and other parts of the plant in summer. (See Figure 5.) It was first described in New York State by Parrott, where it attacks the pear leaf blister mite. Other mites are also attacked. The predacious mite is very active, moving from bud to bud in a few seconds.

During the winter this predacious mite may be found between the bud scales, where many blackberry mites are located These mites are light to amber in color, approximately .5 mm. in length. Their eggs are nearly spherical, transparent at first, later changing to white.

The life history of the predacious mite is closely related to the blackberry mite. Hibernation is in the adult stage. The first eggs of the predacious mite were observed March 16 when four eggs were found in a bud. In contrast to this, the first eggs of the blackberry

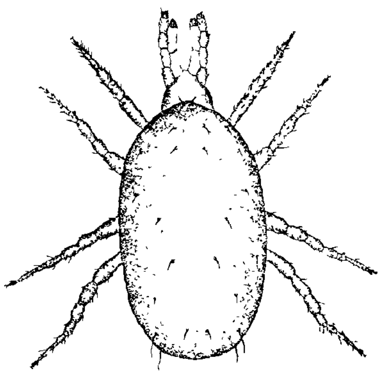

Figure 5. Predacious mite Sejus pomi **Parrott.**
Enlarged 64 times.

mite were observed on March 8. Eggs of the predacious mite are deposited in the berries, buds and occasionally on the leaves. As a rule the eggs are laid singly, occasionally in groups of two or three under a bud scale. These eggs are usually deposited in close proximity to available food. For instance, two predacious mite eggs were observed April 19, 1932, under a bud scale among a group of 26 blackberry mite eggs together with four adults.

The number of predacious mites in the buds varies; as many as nine were observed in a single bud. Whenever a victim is selected, it is picked up in the mandibles and the body fluid extracted, after which the victim's body is dropped in a collapsed condition. Oftentimes the predacious mite stops and picks up a blackberry mite in its mandibles and walks on, stopping only to drop the collapsed body. At all periods of the year the blackberry mite is subject to the attacks of this predacious mite, which represents a most important factor in reducing the number of mites in the blackberries during the winter months.

Control Measures

Spraying experiments on the control of the blackberry mite at the Western Washington Experiment Station were conducted upon 80 plots, with four plants in each plot. Every third row was sprayed three times in order to serve as a buffer and check the natural spread of mites from row to row. Each plot was given a different treatment, which consisted either in a variation in concentration of spray material or in the application of the same concentration at different times. Sprays were applied on the following dates: October 16 and November 25, 1931, February 23 to March 3, April 12, May 16, and July 18, 1932. After the February-March application buds from 19 plots were dissected under a binocular microscope and the number of mites recorded. Table 1 indicates the results of this examination.

During the last week of September, 1932, the berries on 100 laterals from each plot were counted and classified in four groups: harvested berries; ripe but unharvested berries; partly red berries; and red berries. The value of the various spray treatments was determined on the basis of an examination and classification of berries and also on an examination of buds.

Lime-sulphur: Sulphur compounds as insecticides are particularly useful for the control of mites and thrips. They have a definite toxicity toward the former and as a result they are used extensively for the control of spider mites. The toxic effect of sulphur is of two kinds: first, by direct contact; second, through the volatility of the sulphur; the effects of the fumes on the mites.

This was clearly shown in March, 1932, when closed buds were examined after being sprayed with lime-sulphur. Many mites had been killed inside the buds, even though the sulphur spray did not come in direct contact with them. In some buds mites were killed in the terminal end, while live, active mites were observed at the base of the scale, showing that the distance which the sulphur fumes act is not far.

Berries sprayed late in August, 1931, with lime-sulphur 4-100, showed many live mites in the fruit when examined a few days thereafter, even though the berries were covered with a heavy residue of

Table 1. Record of Mites Observed in Buds Following Various Spray Treatments. Buds Dissected under Binocular Microscope

Material and date of application		Number of buds examined	Predacious mites (Sejus pomi)	Blackberry mites between bud and leaf	Blackberry mites inside of bud	Average number blackberry mites per bud	Comparative rating
Lime-sulphur (6-100) Oct. 16, 1931	1	100	0	0	0	0	1
Lime-sulphur (8-100) April 12, 1932	10A	50	16	0	36	.72	5
Lime-sulphur (8-100) Feb. 18, 1932	(30+21)	100	17	1	100	1.01	8
Lime-sulphur (6-100) Feb. 18, 1932	(19+32)	100	7	3	210	2.13	11
Lime-sulphur (4-100)	(20+31)	100	12	7	179	1.86	10
Lime-sulphur (2-100)		100	10	33	432	4.65	16
Lime-sulphur 5% Summer Oil 3% Nov. 25, 1931	5	100	19	0	0	0	1
Lime-sulphur 5% Summer Oil 3% Feb. 19, 1932	17+34	100	6	0	34	.34	3
Lime-sulphur 3% Summer oil 2% Feb. 23, 1932		100	13	1	66	.67	4
Dormant Oil 4% Oct. 16, 1931		100	4	0	28	.28	2
Dormant Oil 4% February 23, 1932		100	30	19	219	2.38	12
Dormant Oil 3% February 29, 1932		150	44	22	127	.99	7
Dormant Oil 2% February 29 1932		100	17	14	64	.78	6
Dormant Oil 1% February 29, 1932		50	4	0	58	1.16	9
Dormant Oil 3% Nicotine Sulphate (1-700) February 29, 1932		100	44	46	414	4.56	15
Nicotine Sulphate (1-500) February 29, 1932		100	6	154	289	4 43	14
Evergreen (1-500) February 23, 1932		50	5	93	270	7 26	18
Garden Whale Oil Soap (1-20) February 23, 1932		50	3	34	223	5.14	17
Summer Oil 3% April 14, 1932		50	44	4	197	4.02	13
Check		100	8	76	904	9.80	

Table 2. Counts of Berries Following Single Applications of Lime-Sulphur, September, 1932

Material and date of application	Harvested berries	Ripe unharvested berries	Partly red berries	Red berries	Per cent red or partly red berries	Comparative rating
Lime-sulphur (6-100) Oct. 16, 1931	2519	128	17	22	1.45 +	5
Lime-sulphur (2-100) Feb. 18, 1932	1323	133	117	519	30.40 +	66*
Lime-sulphur (4-100) Feb. 18, 1932	2512	330	42	97	4.66 +	19
Lime-sulphur (6-100) Feb. 18, 1932	2512	302	53	107	5.38 +	25
Lime-sulphur (8-100) Feb. 18, 1932	2418	317	76	181	8.59—	40*
Lime-sulphur (8-100) Feb. 17, 1932	2436	306	112	266	12.11—	51
Lime-sulphur (4-100) Feb. 18, 1932	2461	210	64	177	8.31 +	38
Lime-sulphur (2-100) Feb. 18, 1932	2472	253	102	205	10.13—	48
Lime-sulphur (2-100) April 12, 1932	2249	161	87	213	11.07 +	49
Lime-sulphur (4-100) April 12, 1932	1721	255	87	200	12.68 +	52
Lime-sulphur (6-100) April 12, 1932	2200	206	60	139	7.64—	34
Lime-sulphur (8-100) April 12, 1932	2102	199	60	158	8.65 +	41
Lime-sulphur (1-100) May 16, 1932	3142	275	85	205	7.82 +	37
Lime-sulphur (2-100) May 16, 1932	2605	216	66	210	8.91 +	45
Lime-sulphur (2½-100) May 16, 1932	2678	153	67	165	7.51—	32
Lime-sulphur (3-100) May 16, 1932	2609	170	69	192	8.59—	40*
Lime-sulphur (4-100) May 16, 1932	2672	177	48	96	4.81 +	21
Lime-sulphur (5-100) May 16, 1932	2450	200	37	106	5.12—	24
Lime-sulphur (1-40) May 16, 1932	1565	230	191	724	33.76	70
Lime-sulphur (1-40) July 16, 1932	2033	348	3	15	.75 +	2
Lime-sulphur (1-40) July 16, 1932	2105	516	4	2	,23—	1
Check	1746	336	443	3270	64.07 +	

* Duplication

the spray. Lime-sulphur, 6-100, applied October 16, resulted in 100 per cent control, judging from the examination of 100 bud samples under a binocular microscope. The effectiveness of this fall application was further shown when the fruit was classified as previously indicated.

Of the 76 plots, which included treatments with lime-sulphur, mineral oil, whale oil soap, Evergreen, and Black Leaf 40, the ten standing highest in control were treated with lime-sulphur or wettable sulphur in one way or another. In the examination of cane buds from 19 different plots after the February-March spraying, lime-sulphur was used in the first six giving the best control. Two of the six were combinations of lime-sulphur and oil, which illustrates the effectiveness of sulphur in mite control. Table 2 shows the results of this examination so far as lime-sulphur is concerned.

Wettable Sulphur: Wettable sulphur is a form of sulphur treated so as to allow the sulphur to go into suspension with water. It may be used for the foliage spray in May. The spreading quality of wettable sulphur, however, was not so good as lime-sulphur. In the case of the July 18 application the use of wettable sulphur, five pounds to 100 gallons of water, gave results nearly equivalent to lime-sulphur, 1-40.

Lime-sulphur-Oil Combination: The lime-sulphur-oil combination, applied during February, was the most effective dormant spray treatment, considered from the standpoint of both bud examination and classification of berries at harvest. This combination increases the efficiency of both the oil and sulphur.

No injury resulted when the lime-sulphur-oil combination was used late in February. Severe injury resulted, however, when the material was applied November 25. The leaves dropped from the canes within a month after the application and some of the cane buds showed injury.

The lime-sulphur-oil combination may be used safely only in February. Two gallons of commercial oil and three gallons of lime-sulphur to 100 gallons of water proved as efficient as three gallons of oil and five gallons of lime-sulphur to 100 gallons of water.

Oils: Both dormant① and summer② oils were used in the experiments at Puyallup in 1932. The mineral oils gave a better penetration than did lime-sulphur, Evergreen, whale oil soap, or nicotine sulphate. This penetration, however, was not sufficient to assure control and in comparison with the sulphur compounds the oil is less efficient.

In order to kill, the mineral oil must penetrate directly into the mite. The oil residue on the plant is non-toxic, since many mites were ob-

① Dormant oil. 72-75% unsulphonated residue; 110 viscosity Saybolt.
② Summer oil. 90-93% unsulphonated residue; 80-85 viscosity Saybolt.

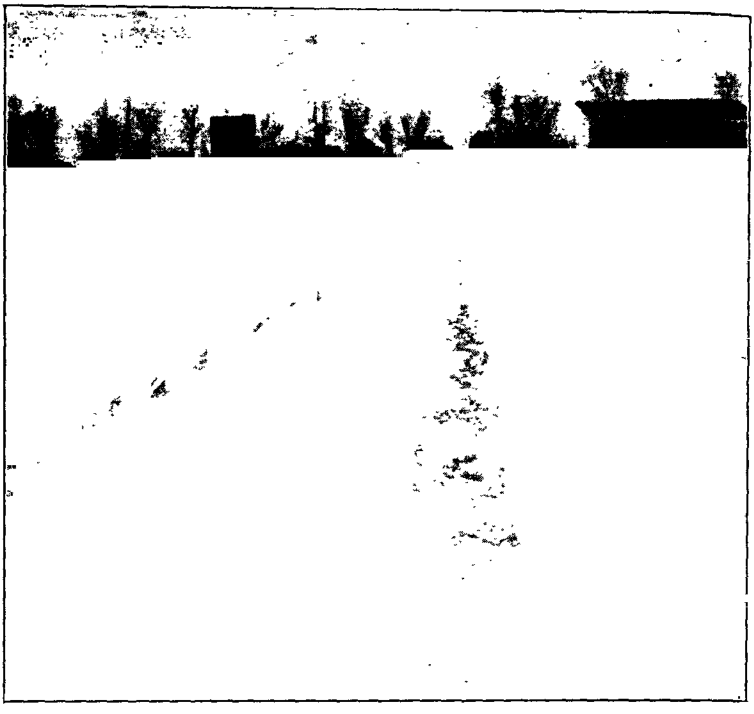

Figure 6. Trained canes ready for the first spray application.

served crawling over the oil film on the buds. The only period during the year when mineral oil shows promise is in summer after the fruit is set. At that time it is unsafe to use sulphur because of the residue on the fruit, which renders it objectionable for canning purposes.

Nicotine Sulphate: The nicotine sulphate was used at one part to 500 parts of water. The spray did not adhere well to the foliage nor did it penetrate into the buds. In an examination following this treatment a relatively high mite count was recorded. At harvest time the plot sprayed February 29 with nicotine sulphate 1-500 showed 36 per cent red or partly red berries. Plots sprayed twice, February 29 and May 21, showed 30.5 per cent red or partly red berries. When the nicotine-oil combination was used (nicotine 1-700, 3 per cent oil), the insecticidal value of both materials was increased and the number of red and partly red berries reduced to 6.29 per cent for the two applications in February and May. A single application of nicotine-oil in

February resulted in 8.98 per cent of infected fruit. In general, the control obtained with nicotine-oil was not sufficiently satisfactory to warrant recommending the combination.

Evergreen: Evergreen, a commercial pyrethrum extract, was used in two plots at the concentration of 1-500. As in the case of nicotine sulphate, this spray did not adhere well to the foliage and resulted in a poor penetration into the buds. The bud examination showed a high carry-over of live mites after the February application.

When checking the results at harvest time, the plots sprayed with Evergreen, 1-500, February 23, showed 50.7 per cent red or partly red berries. The plots sprayed on February 23 and May 16 showed 44.25 per cent red or partly red berries. Taking into consideration the fact that the check or untreated plots showed a total of 64.07 per cent affected fruit, it is apparent that the Evergreen was of little value for blackberry mites.

Whale Oil Soap: Liquid whale oil soap was used at the rate of 1-20, in February and again in May. A satisfactory coverage was obtained, but the penetration into the buds was inadequate. Whale oil soap falls approximately in the same group, as far as mite control is concerned, with nicotine sulphate and Evergreen. The records show 34 per cent red or partly red berries following the one application in February and 32 per cent for the plots sprayed in February and again in May.

Injury from Spray Material

Injury to Evergreen blackberries resulted following late applications, mainly in July. The application of lime-sulphur, 1-40, wettable sulphur, (5 lbs. to 100 gal.) and 2 per cent summer oil on July 18 caused a yellowing of the foliage during August and September. No injury resulted from the oils and wettable sulphur applied during May.

Lime-sulphur and oil applied November 25 caused a dropping of the Oregon Evergreen leaves, complete defoliation taking place during December. No injury resulted when the same application was repeated in February. Oil applied on February 22 to canes, followed by wettable sulphur or dilute lime-sulphur May 16, produced no toxic effect on the plants.

Summary of Control Experiments

The same materials give variable results when used at different times in the year. The reason for this variation may be explained by the ability of the sprays to actually come in contact with the mites and so cause a reduction in mite population. The fall application is effective because a greater percentage of the mites have not entered the bud at that time. Those mites inside the bud tend to be located toward the tip, the majority being found between the compound leaf

and the cane bud. In this location the mites are more easily contacted by the spray material.

In February a greater percentage of the mites have moved into the bud and as a result are protected from the spray; a smaller percentage remains between the bud and the compound leaf. Those mites which are not killed by the spray represent a carry-over that results in affected fruit the following summer. The application of lime-sulphur, 1-40, July 18 was the most effective spray treatment because the mites were easily contacted by the material when they were migrating from the bud to the fruit. The spray at that time cut down the mite population to such an extent that it was unable to recover sufficiently and cause serious injury.

Bud Examination and Efficiency of Spray Treatments

In discussing the efficiency of various spray materials from the standpoint of bud examination the following spring, consideration must be made of the variable factors. Buds in a field that show 60 per cent loss of crop in the summer will show great variation in the number of mites per bud in February and March. In checking the buds, the object was to select 100 buds from each plot treated with different materials or the same materials at various concentrations The number of live mites present in the buds indicated the type of control that had been obtained following the use of these spray materials.

When attempting to correlate the per cent of red and partly red berries at harvest time with the average number of live mites per bud in the 20 plots checked in February and March, a correlation of .36 only was obtained, with a probable error of .0131. The correlation shows that the relation between the mites and per cent of red or partly red berries is not sufficiently high to show reliable relationship. A number of agencies may be contributing factors in throwing off the correlation. First, there is the spread of mites in a field by reason of air currents which may result in greater infestation in a plot near or adjacent to one that has not received a satisfactory control treatment. Again, there is the uneven distribution of the predacious mites.

It is of interest to note, however, that the plots sprayed with lime-sulphur, 6-100, October 16, showed by inspection the least mite infestation in the buds after spray application and had also the least percentage of red or partly red berries at harvest time. Conversely, the untreated plot had the greatest number of red or partly red berries, and the highest mite count. In this case an average of 9.8 mites per bud in March resulted in an infestation which caused 64.07 per cent of red or partly red berries at harvest time.

Cane Bud Development and Relation to Control

Since difficulty arises in forcing an insecticide into closed blackberry buds, it is important to ascertain the relationship of the mites in the buds and the stage of development of the bud at all periods of the year. The Oregon Evergreen blackberry is a plant that never goes through a completely dormant period. There is no period during the fall or winter when it is entirely defoliated. Old fruiting canes die in the fall, but the new canes retain their leaves throughout the winter.

In obtaining a record of bud development, photographs were taken of buds on four portions of a cane. The first of these was located approximately 1½ feet from the end of the cane, the second, 3½ feet from the end; the third, 4½ feet; and the fourth, 5½ feet from the end of the cane. The location of the mite was noted at the time each photograph was taken. In the fall the first photograph was taken October 16, and the next February 22. After that date, photographs were taken at approximately ten-day intervals up to and including July 18.

During the period from October 9 to 22 there was little external change, the buds being slightly swollen, with the bud scales slightly more expanded. Not much change was observed after October. Many mites at this period of the year were in the axis between the cane bud and the compound leaf, a lesser number within the bud. In February the bud was too compact to permit good penetration of the spray liquid.

In early March there was a slight swelling of the buds with more mites working in between the bud from the previous location in the axis between the compound leaf and the cane bud. The buds continued to enlarge slightly. The buds that showed the greatest development were those largely toward the base of the cane. From March 27 to April 14, there was gradual enlargement of the bud. On April 14 the buds from 3½ feet of the base of the cane showed growth up to two inches. It was not until April 24, ten days later, that the cane buds at the end of the cane had produced two inches of growth, at which time many of the laterals 5½ feet from the end of the cane showed a growth of six inches.

After lateral growth had started development, the mites did not progress with the new growth but remained under the scales of the old winter cane buds. On May 16 lateral growth had advanced, but very few flower buds had started to form It was not until June 1 that a large percentage of the laterals showed the flowers in the green bud stage.

On June 15 many of the terminal buds were in bloom. Blooming continued throughout the summer, and a great percentage of the fruit had set by July 18.

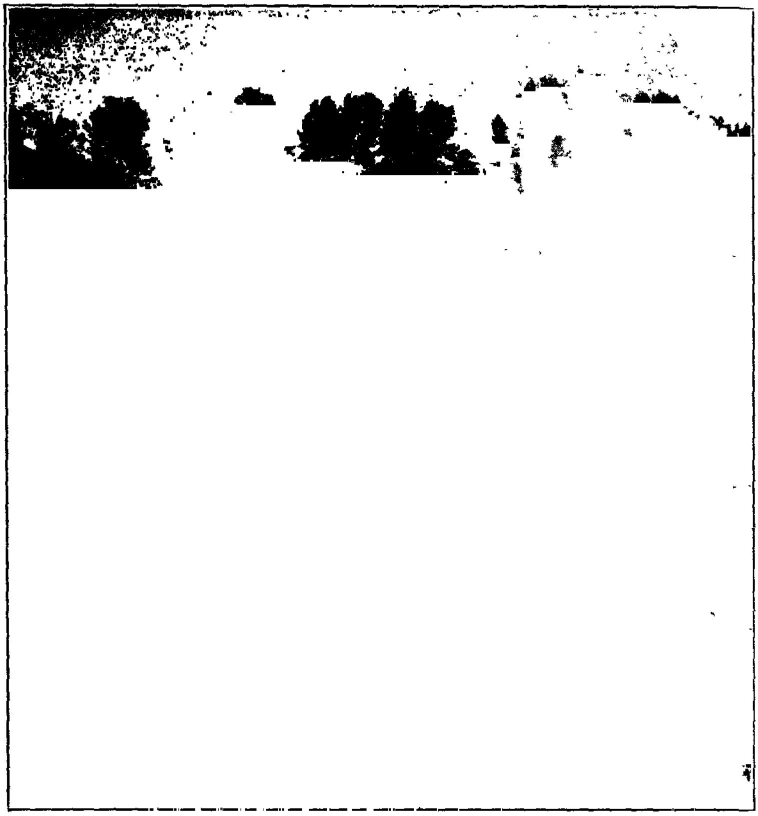

Figure 7. Blackberry planting when the May application should be applied.

Spray Program Recommended

The most effective spray program is the use of liquid lime-sulphur, 32° Baumé, five gallons to 100 gallons of water, applied after the old canes have been removed in the fall. This should be followed with a second application of lime-sulphur 1-40 during the period between May 10 and May 20. (See Figures 6 and 7.)

An alternative spray program is that of lime-sulphur, 7-100, applied between March 15 and April 1, with a second application of lime-sulphur (1-40 or wettable sulphur five pounds to 100 gallons) between May 10 and 20.

The most effective single application is a spray of lime-sulphur, 1-40, applied in the neighborhood of July 18. This spray cannot be recommended, however, when the fruit is to be used for canning because of objectionable residue.

If a summer spray is desirable, refined summer oils should be used. This application should not follow a sulphur spray, because of danger of foliage injury.

Where the fruit is used for canning, the best single spray treatment is the fall application of lime-sulphur spray (5-100).

A thorough coverage is essential for a satisfactory control.

Summary

1. The blackberry mite first came to the attention of the berry industry in the Pacific Northwest in September, 1930.

2. The life history in Washington varies somewhat from that of the mite in California and England. Migration from the hibernation quarters is from the scales of the old winter cane bud to the lateral buds, then to the fruit, instead of from the bud to the open flower.

3. In mite-infested fields, the early berries will often ripen before the mites become established in the fruit. In 1931 the estimated harvested unaffected fruit of the total crop was 35 per cent. In 1932 the check plots showed 35.93 per cent harvested normal berries.

4. Infestations in Washington include the more important cultivated districts of the state.

5. The introduction of the mite into Washington was apparently through the movement of berry crates from an Oregon cannery.

6. The injury caused by the mite is through its feeding at the core and at the base of the drupelets, causing the berry to remain red instead of ripening normally.

7. A predacious mite is responsible for destroying many blackberry mites but does not control the pest.

8. As soon as the berry harvest is completed, old canes should be removed and burned This practice will destroy many mites before they reach the new cane buds.

9. In October after the old canes are removed, apply lime-sulphur, 5-100, to the new canes on the lower trellis wire. Follow this with lime-sulphur, 1-40, in a period from May 10 to May 20.

10. If the spring program is preferred, spray with lime-sulphur, 6-100, in the period from March 15 to April 1. Follow this with a lime-sulphur spray, 1-40, in the period from May 10 to May 20

11. No sulphur sprays should be applied after May 20 if the fruit is to be used for canning.

References

1. Darrow, George M., European Blackberry Seedlings in the Pacific Northwest. Jour. Hered. 22: 143-146. 1931.
2. Essig, E. O., The Blackberry Mite; the Cause of the Redberry Disease of the Himalaya Blackberry and Its Control. Calif. Agr. Exp. Sta. Bul. 399: 1-10. 1925.
3. Ewing, H. E., The Common Red-Spider or Spider Mite. Ore. Agr. Exp. Sta. Bul. 121: 53-55. 1914.
4. Hassan, A. S., The Biology of the Eriophyidae with Special Reference to *Eriophyes tristriatus* (Nalepa). Univ. Calif. Pub. Entom. 4: 341-394. 1928.
5. Massee, A. M., The Blackberry Mites. Jour. Pomol. and Hort. Science 9: 298-302. 1931.
6. Mote, Don C., Redberry Disease of Blackberries. Better Fruit 25: 10. 1930.
7. Mote, Don C., Redberry Disease of Blackberries in Oregon. Ore. Agr. Exp. Sta. Circ. of Information, No. 40. 1930.
8. Mote, Don C. and Wilcox, J., Proc. 27th Annual Meet. Wash. State Hort. Assn. 203-207. 1932.
9. Yothers, W. W., The Citrus Rust Mite and Its Control. U. S. Dept. of Agr., Tech. Bul. 176. 1930.

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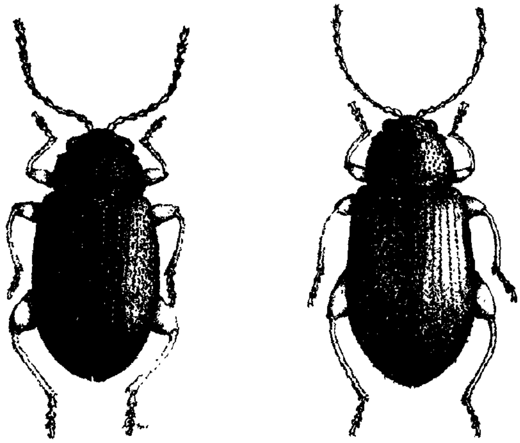
THE POTATO FLEA BEETLES
Epitrix cucumeris Harris
Epitrix subcrinita Leconte

By Arthur J. Hanson*

Introduction

An epidemic of potato flea beetles has occurred in certain parts of western Washington since 1925, when *Epitrix cucumeris* first became of economic importance in the state. The serious tuber injury on potatoes started with the establishment of this species, the common potato flea beetle of the eastern states, in Pacific and Grays Harbor counties.

The western potato flea beetle, *Epitrix subcrinita,* (Fig. 1) has been reported destructive in Oregon and Washington at intervals since 1913.



(a) (b)

Fig. 1. (a) Epitrix cucumeris. **Potato flea beetle. Enlarged 17 times. (b)** Epitrix subcrinita, **Western potato flea beetle. Enlarged 17 times.**

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The author wishes to acknowledge the receipt of assistance from R. L. Webster, H. V. Hanson and Leslie Sorensen.

Injury by this species was periodical and of little importance until the establishment of the eastern species. Each year *Epitrix cucumeris* has been extending its area of destruction, and is responsible for the abandonment of potato growing for the commercial market in some sections. Because of tuber injury, potatoes grown in these districts are of inferior quality, and are used mainly for home consumption.

This insect has been reported as a potato pest from almost every state east of the Rocky Mountains from Maine to Colorado and New Mexico. In Kentucky, however, Jewett (6) reports the greatest injury from the eggplant flea beetle, *Epitrix fuscula* Cr.

Review of the Literature

The literature on potato flea beetles is extensive. Life history studies have been conducted by Stewart (10) in New York; Johannsen (7) in Maine; and Webster (11) in Iowa; Hoerner and Gillette (5) in Colorado; Jewett (6) in Kentucky; and Webster, Baker, and Hanson (13) in Washington. In the northern states the investigators largely agree that there is one generation annually. Jewett (6) reports two generations a year in Kentucky.

The period at which the adults emerge from overwintering quarters does not appear to vary to any great extent throughout the country. They leave hibernation in May and June, migrating to a desirable host plant. Those selected are usually members of the nightshade family, Solanaceae.

Host Range

Potato flea beetles have been reported living upon a large number of plants. To determine the food plants of both adults and larvae, a number of reported host plants were grown in a Grays Harbor county potato field. Observations were made at intervals to determine the extent that adults feed upon the foliage and the presence of larvae on the roots.

Foliage injury was limited to the potato, eggplant, golden husk tomato, and tomato until the new generation appeared in July. (See Fig. 2.) This new generation of adults was less selective among the plants, although they still retained the preference for the Solanums. Late in August the adult beetles were observed on all of the host plants used in the experiment and in addition some of the native grasses, such as nettle, and rush.

Larvae or pupae were located around the roots of the following: eggplant, golden husk tomato or ground cherry, potato, tomato, and the Chinese lantern, *Physalis francheti*. Neither larvae nor pupae were located around the roots of the following plants: anemone, aster, balsam, bean, beet, blackberry, broccoli, carrot, Swiss chard, red clover, corn, cosmos,

Fig. 2. Tomato plants may be severely injured by the feeding of the beetles. The foliage and the stems are subject to severe injury in August and September.

cucumber, dill, endive, kale, larkspur, lettuce, lupin, marigold, muskmelon, mustard, nasturtium, parsley, sweet pea, pepper, phlox, pumpkin, radish, spinach, strawberry, squash, and turnip.

These observations indicate that the host range in the larval stage is limited mainly to plants belonging to the Solanaceae.

Life History

The potato flea beetle deposits its eggs near the base of the selected host, usually the potato. These eggs hatch into small larvae which work into the soil and feed upon the roots and developing tubers. After completing the larval stage they transform to pupae and then to the adult beetle. (See Fig. 3.)

Hibernation takes place in the adult stage either in the soil of the old potato planting or in debris about the field. Occasionally a few individuals may go through the winter in moss, or on the bark of trees. Flea beetles placed in cages in an outdoor insectary went into the soil for hibernation in September and October, reappearing in the cages during early June of the following year.

The first potato plants attacked in the spring are volunteers coming from unharvested tubers. The leaves on these plants may become

(a) (b) (c)

Fig. 3. Epitrix cucumeris, (a) egg (x26); (b) larva (x12); and (c) pupa (x14)

completely perforated with small holes. (Fig. 4.) The beetles soon leave these plants, since there is only a limited number of them. Migration then takes place to the potato field, with the outer rows of the planting first subject to the infestation. Later, the distribution tends to be general throughout the planting.

Fig. 4. Potato flea beetle injury on foliage often becomes so serious that the potato plants are killed.

As the season advances, the number of adult beetles increases in the ratio illustrated in Figure 5. They start to enter the field late in May, and a gradual increase occurs throughout June. Many of these overwintering adults die early in July, a drop of the curve resulting. The greatest increase in adult population takes place in the period from July 15 to August 15. This is due to the fact that flea beetles are completing their developmental stages in the soil. After August 25,

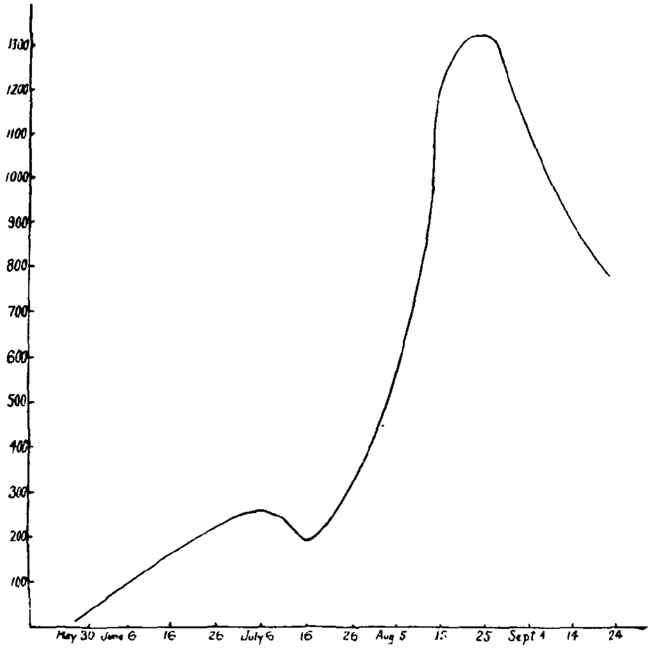

Fig. 5. The number of flea beetles increases as the season advances, then decreases as the flea beetles go into hibernation. The curve is the result of plotting the number of flea beetles in the check plot against the date of observation.

the peak is reached, and a decline starts in with some of the beetles migrating from the potato planting. In September and October the flea beetles go into hibernation and by November 1 the curve again approaches zero, indicating complete disappearance from the field.

The seasonal increase in foliage injury as represented in Figure 6 is also an index to the increase in population in the potato planting. Late in July, with a continual emergence of adult beetles from the

soil, there is a steady increase in foliage injury. During the latter part of August many of the plants were killed. This foliage injury is cumulative, however, although the total leaf surface of the plant is continually increasing throughout the growing season.

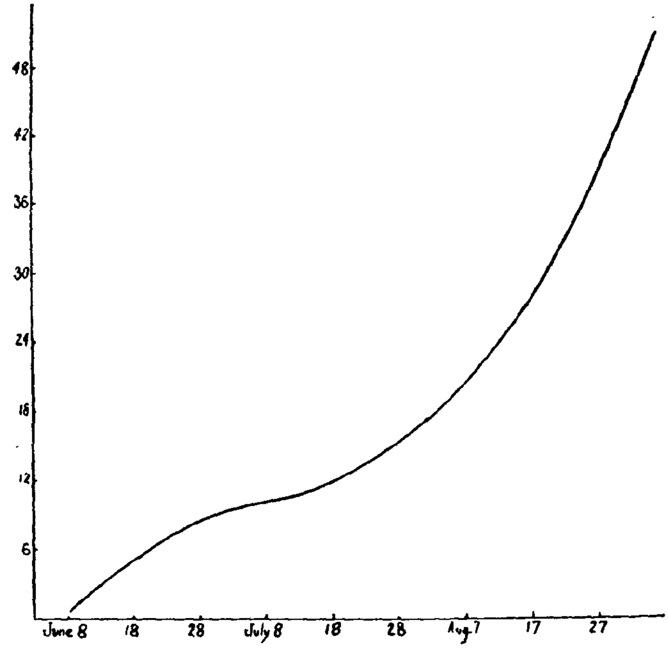

Fig. 6. The foliage injury increases as the summer advances. This curve is the result of plotting amount of injury per leaflet against the date the sample was taken from the plot. Early Rose variety. Brady, Wash. 1932.

Natural Enemies

In Washington a nematode and an entomaphagous fungus are the only parasites of the potato flea beetle that have been observed. *Perilitus epitricis* Viereck, recorded by Cameron (1) and the hymenopterous parasite reported by Forbes (3), which may be one and the same, have not been recorded in this state.

Parasitic Nematode. A nematode closely related to *Howardula benigna* Cobb was located in a number of larvae of *Epitrix cucumeris*. They were observed inside the abdomen, some in the anterior segments, others in the posterior segments.

The extent of parasitism by this nema in Washington is not established.

Entomophagous Fungus. A species of Entomophthora causes the death of some adult flea beetles each year. This has not been an epidemic among flea beetles so far as observed, and inoculation tests conducted caused only a low mortality.

Western Potato Flea Beetle Causes Tuber Injury

Previous investigations by Webster (12) in Washington have indicated that the western potato flea beetle is a root feeder in the larval stage. In other words, that species confines its feeding largely to the root system rather than on the developing tuber. In sections where the western species is the only one present, the tuber injury is not serious.

To study the larval feeding habits of the two species, beetles were segregated and confined to potted plants in the insectary at Puyallup. Tuber injury was recorded on potatoes that were subject to the larvae of both species of flea beetles. Adults of *Epitrix subcrinita* were confined on 36 potted potato plants, and a total of 134 tubers harvested from these plants, of which 26 (19.4 per cent) showed larval injury. On the other hand, *Epitrix cucumeris* was confined to 10 potted plants and 32 tubers harvested, of which 13 tubers (40.6 per cent) showed larval injury.

It is, therefore, apparent that the western species feeds on the tubers, although probably to a less extent. Under field conditions the injury is less severe, likely because this species is not so numerous.

Planting Dates in Relation to Flea Beetle Injury

The dates on which potatoes are planted during the season have a direct bearing on the severity of flea beetle injury to tubers. This is largely due to the life history of the insect, since there is only one complete generation annually, and a partial second generation. To determine the influence of planting dates on the relative amount of injury, Early Rose potatoes were planted at 10-day intervals starting on March 1, and ending on July 18 in a 4-acre experimental plot at Brady, in Grays Harbor county.

After the potatoes had matured, the tubers were checked for larval injury on the surface and scored according to the length of the surface channel and the number of larval punctures. The average injury per tuber was plotted, the record being shown in Figure 7. The greatest amount of injury was present on those tubers harvested from potatoes planted in the period April 19 to May 29. During March a gradual increase occurred.

If early potatoes could be matured by July 8, the serious tuber injury would be eliminated. Potatoes will mature earlier in the Puget Sound district than in those counties adjoining the Pacific Ocean. In

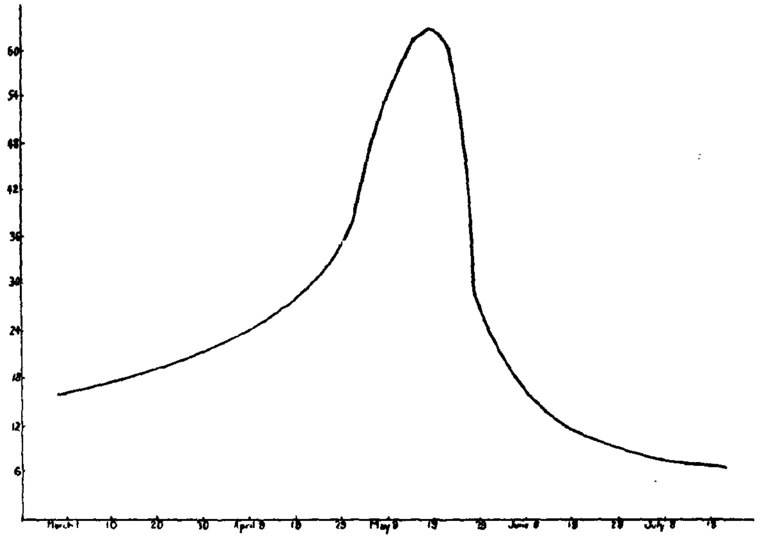

Fig. 7. Relation of planting date and the amount of injury on the tubers. The curve is the result of plotting the average amount of injury per tuber against the planting date. Early Rose variety. Brady, Wash. 1932.

Grays Harbor and Mason counties the seasons are later and only under the most favorable weather conditions have potatoes been ready for harvest by July 8. If this were possible each year, early potatoes could be grown relatively free of tuber injury without the use of any insecticide.

The plots of Early Rose potatoes planted at 10-day intervals from March 1 to April 19 tended to approximate the same stage of growth during the latter part of June. Potatoes planted March 1, 10, and 20 started to grow earlier, but the rate of growth was slow because of cold weather.

The time of the year that larval injury occurs is illustrated in Figure 8. The curve represents the average injury per tuber on samples taken from the same plot at 10-day intervals in 1932. The tuber injury started the latter part of June, increased slowly until July 8, while the greatest amount of injury took place between July 8 and July 18. After July 18 not much additional injury occurred, and as a result the curve straightened out. The main significance of the curve is that most of the larval injury took place between July 8 and July 18. Planting potatoes for maturity in July or planting them late makes it possible to eliminate a large portion of this tuber injury.

Late Potatoes. Late potatoes in western Washington refer to those planted after June 1, usually in the period from June 15 to July 15. Potatoes planted during this period develop tubers relatively free from injury. The absence of injury may be accounted for by reviewing the life history of the insect.

The majority of the beetles leave hibernation, migrating to potato fields in the period between May 15 and June 20. By the time late potatoes are starting to grow the insect has passed through its migratory period. Once the beetles become established in a potato field there is little migration to other fields.

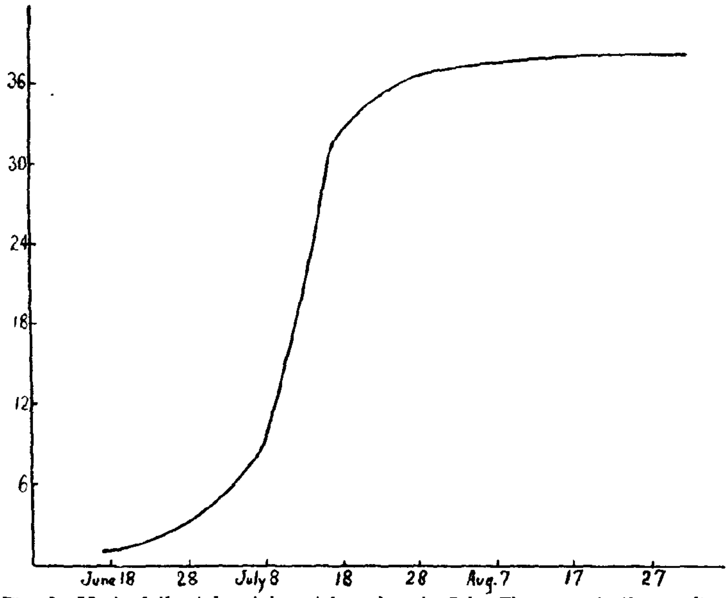

Fig. 8. **Most of the tuber injury takes place in July. The curve is the result of plotting the average injury per tuber in a sample selected from the same plot at 10-day intervals. Earliest of All variety. Brady, Wash. 1932.**

The migration period is then completed before late potatoes start to grow. This permits the tubers to develop with very little injury, even though they may be causing serious tuber damage in a nearby field of early potatoes.

Late plantings, however, will not insure freedom from injury when the potatoes are in close proximity to earlier planted potatoes. In such cases the insect moves readily from the early to the later plantings.

Late blight disease, caused by the organism *Phytophthora infestans,* is one of the main limiting factors of late potatoes. Favorable climatic conditions for late blight were present throughout the summer of 1932 in the experimental planting in Grays Harbor. Frequent rains which were conducive to the development of the fungus occurred in July and August. The vines in some fields had succumbed to the disease by August 17. In 1931 late blight did not appear in this locality until October 7. This disease was satisfactorily controlled with the Bordeaux mixture spray.

Larval Injury

The feeding of the larvae on the root system and tubers is the most injurious feature of the insect's attack. This disfigurement of the potatoes makes them inferior in quality and often unmarketable. This larval injury is repaired in the developing tuber by the formation of cork cells. After this process is completed, the lesion may remain largely unnoticed, unless complications set in with bacteria and fungi. When these potatoes are prepared for culinary use, an additional amount of the tuber must be removed to eliminate these cork cells, as shown in Figure 9.

Scab and Flea Beetle Injury. Potato scab caused by the fungus, *Actinomyces scabies,* has been connected with flea beetle injury in Colorado by McMillan and Schaal (9). The larvae may be associated

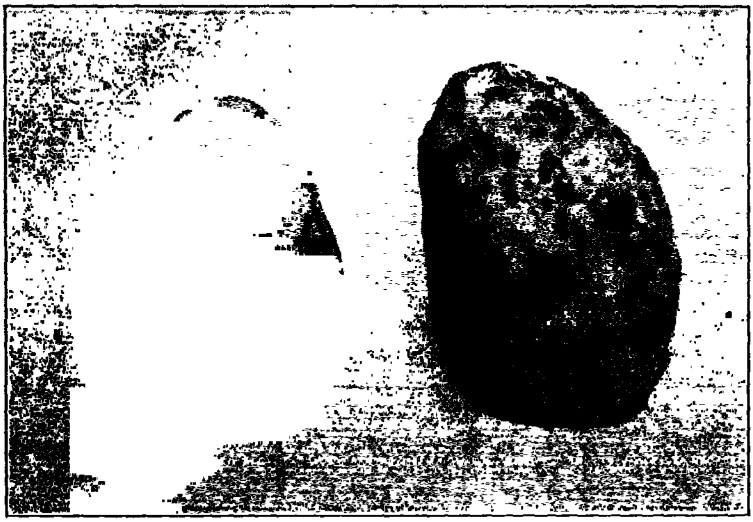

Fig. 9. Severe flea beetle injury in tubers after paring.

in two ways with the scab organism: first, in causing a lesion on the tuber, permitting the entrance of the scab organism from the surrounding soil; second, the larvae may serve as carriers, acting as mechanical agents in spreading the organisms from tuber to tuber. It is apparent that the organism could gain entrance to the tuber more easily through such lesions. Some tubers showed on examination that the scab organism followed the surface channels where the primary injury was caused by the larvae, as indicated in Figure 10.

Fig. 10. Potato scab in conjunction with flea beetle injury. On these tubers the scab has followed the larval injury.

In determining the relation of scab in conjunction with flea beetle injury, 128 hills of Gold Coin variety were planted, each seed piece having one or more scab lesions on it. After the potatoes had matured, a representative sample of 350 tubers was scored according to the number of scab lesions and the number of surface channels, exit holes, and entrance holes caused by the larvae. The flea beetle injury averaged 26.84 for 350 tuber samples, while the average number of scab lesions per tuber was 6.1. It was also shown by examination that 41 per cent had one or more scab lesions.

When correlating the number of scab lesions with the amount of injury on the tuber, using the product-moment method, a correlation of .36 was obtained, with a probable error of $\pm$ .03. The coefficient is not high enough to show dependable relationship between the spread of scab organism and flea beetle injury.

Rhizoctonia and Flea Beetle Injury. One of the most serious complicating factors in growing potatoes in districts subject to flea beetle injury is its frequent association with Rhizoctonia. The symptoms are the enlargement and opening of the tunnels made primarily by the larvae. The necrotic tissue may become sunken and more cork cells necessarily are produced in order to repair the injury, as shown in Figure 11. The sclerotia form in the channels as well as upon the surface of

Fig. 11. Rhizoctonia causes the surface channels to become enlarged with the injury becoming more serious. Early Rose variety.

the tuber. As in the case of scab, flea beetle larvae may be associated with Rhizoctonia in opening lesions and in the spread of the organisms on the developing tubers. Without these bacteria and fungi, flea beetle injury is much less evident. (See Fig. 12.)

In making observations on the relation of flea beetle injury and Rhizoctonia, 128 hills were planted, Rhizoctonia being present on each seed potato. After the tubers had matured, a sample of 200 potatoes was examined. Of these, 187 had Rhizoctonia sclerotia on the tubers, with surface injury that had enlarged instead of healing over; nine tubers had enlarged surface injury with no sclerotia; three tubers showed flea beetle injury with no Rhizoctonia; while one tuber was entirely free from injury. These observations, together with previous field notes, showed that Rhizoctonia is definitely related to enlarged surface channels and increased injury. Because of this relationship, seed treatment and crop rotation become more important in flea beetle districts.

Fig. 12. In the absence of fungi and bacteria the larval injury on the tuber is not so apparent. Early Rose variety.

Varietal Resistance. In order to determine the extent of any varietal resistance of potatoes in relation to flea beetle injury, eight of the more common varieties grown in western Washington were selected for a varietal test in plots at Brady. These were planted May 1, in a series of plots consisting of eight rows with 16 hills to a row. After the potatoes had matured, a representative sample was selected from each plot and scored for the amount of tuber injury, as indicated in Table 1. Of these eight varieties, Beauty Hebron showed the most damage per tuber, with approximately four times as much injury as Gold Coin. The latter was the least attacked of any of the eight varieties.

Table 1. Varieties of Potatoes Show Variation in the Amount of Flea Beetle Injury on the Tubers Under the Same Field Conditions. 1932.

Variety	Total tuber score	Number of tubers	Average injury per tuber
Gold Coin	1778	140	12.70
Netted Gem	2417	140	17.25
Irish Cobbler	2664	138	19.30
May Queen	2939	150	19.59
Bliss Triumph	2887	140	20.62
Earliest of All	4524	140	32.31
Early Rose	5128	140	36.63
Beauty Hebron	5874	120	48.95

From the commercial standpoint it is doubtful if the varietal resistance shown is of any great significance. In a planting of potatoes where there is a single variety, beetles will attack that variety regardless of whether or not it is resistant. In general, those potato varieties that are strong growing are most desirable. Weak plants are subject to a greater amount of foliage injury as compared with strong plants, which are able to outgrow some of the severe damage to leaves. Flea beetles appear to show some preference for the weaker, less thrifty hills.

Control Experiments

At the inception of the experiments a review of the literature revealed a wide variation in the insecticides recommended for flea beetle control. Among them were included the contact insecticides, stomach poisons, and repellents. The standard recommendation in the eastern states for years was the use of Bordeaux as a repellent. Recently there has been a change to the recommendation of Bordeaux with calcium arsenate (4) or with lead arsenate (6).

In preliminary tests in 1931 in Grays Harbor county, an attempt was made to correlate or establish a relationship between the control obtained and the various insecticides previously recommended in entomological literature. Nine applications of the sprays and dust were made at 10-day intervals, starting May 30. In checking the final results, the following factors were used to measure the degree of control:

1. The number of flea beetles in the plots eight rows wide and 21 feet long recorded at the end of 10-day intervals. See Table 2.
2. The amount of foliage injury on samples taken July 27 and August 7. Foliage injury was measured by the number and the size of the punctures in the leaflets. See Table 4.
3. The amount of tuber injury at harvest. This was obtained by recording the number of larval entrance and exit holes on the tubers and the length of the surface channels. See Table 3.

The question that first arose was whether a reduction in the amount of leaf injury was generally accompanied by a reduction of tuber injury. If a definite relationship existed, either foliage injury or tuber injury could be used to measure the control obtained.

Following the experiments of 1931, when attempting to establish some relationship between foliage injury (Table 4) and the tuber injury (Table 3), the correlation obtained was .867, with a probable error of $\pm$.044. The correlation found between the total number of beetles (Table 2) at the end of the 10-day intervals and foliage in-

Table 2. The Number of Adult Flea Beetles in the Plots Recorded at the End of the 10-Day Intervals 1931

Material	June 6	June 16	June 26	July 6	July 16	July 26	Aug. 5	Aug. 15	Aug. 25	Total	Rating
4% Nicotine dust	40	91	165	226	256	297	217	540	923	2755	15
Sodium fluosilicate Lime (1-4)	2	62	12	11	53	8	7	19	51	225	1
Noxum dust (Ferrous carbonate)	6	63	16	24	145	19	29	131	197	630	4
Barium fluosilicate Lime (1-4)	1	78	12	6	59	9	7	49	97	318	2
Bordeaux (4-4-50)	85	132	60	93	189	195	308	350	225	1637	10
Bordeaux (4-8-50) Barium fluosilicate 1½lbs.	32	131	60	87	168	178	75	155	115	1001	8
Bordeaux (4-8-50) Sodium fluosilicate 1½ lbs.	27	103	54	113	179	134	71	103	159	943	7
Bordeaux (4-4-50) Basic lead arsenate 1½ lbs.	69	160	121	187	353	408	353	206	163	2020	11
Bordeaux (4-4-50) Calcium arsenate 1½ lbs.	14	118	22	21	133	86	62	187	94	737	5
Barium fluosilicate 1½ lbs. and water - 50 gal.	7	107	18	44	69	35	38	76	135	529	3
Sodium fluosilicate 1½ lbs. and water - 50 gal.	6	116	49	96	123	31	53	156	209	839	6
Calcium arsenate 1½ lbs. and water - 50 gal.	6	114	81	137	117	125	101	158	375	1214	9
Basic lead arsenate 1½ lbs. and water - 50 gal.	53	113	188	185	152	167	213	458	850	2379	12
Evergreen (1-100)	18	98	153	117	104	128	232	575	1065	2490	13
Red Arrow (1-560)	6	63	49	178	114	138	187	610	1125	2470	14
Pyrethrol (1-100)	16	39	85	272	233	246	189	730	1175	2985	16
Check	53	166	186	265	182	367	547	1100	1345	4211	

Tabl ... cord of the Amount of Tuber Injury on Potatoes Protected by ... e Dust or Spray Applications. Early Rose Variety. 1931

Ma ...	Total tuber score	Number of tubers	Average per tuber	Comparative rating
4% Nicotine dust	7072	145	48.77	13
Sodium fluosilicate and lime (1-4)	445	180	2.47+	1
Noxum dust (Ferrous carbonate)	4066	170	23.56	9
Barium fluosilicate (Dutox) and lime (1-4)	847	200	4.24—	2
Bordeaux (4-4-50)	4579	192	23.85—	10
Bordeaux (4-8-50) and Dutox (Barium fluosilicate) 1½ lbs.	2441	149	16.38+	7
Bordeaux (4-8-50) and sodium fluosilicate 1½ lbs.	2714	179	15.16+	5
Bordeaux (4-4-50) and basic lead arsenate 1½ lbs.	4493	174	25.82+	11
Bordeaux (4-4-50) and calcium arsenate 1½ lbs.	2263	173	13.08+	4
Dutox (barium fluosilicate) 1½ lbs. and water - 50 gal.	1817	174	10.75+	3
Sodium fluosilicate 1½ lbs. and water - 50 gal.	1712	105	16.31—	6
Calcium arsenate 1½ lbs. and water - 50 gal.	2156	131	16.46—	8
Basic lead arsenate 1½ lbs. and water - 50 gal.	5419	116	46.72—	12
Evergreen (1-100)	5742	79	72.68+	16
Red Arrow (1-560)	6488	103	62.99+	15
Pyrethrol (1-100)	6473	105	61.65—	14
Check	9919	137	72.40+	

jury was .936, with a probable error of ± .022. The correlation between tuber injury and total number of flea beetles in the plots at the 10-day intervals was .936, with a probable error of ± .023. In other words, there was a high degree of correlation in all three cases.

From these results it was concluded that, if the flea beetles are reduced in numbers by any insecticide, a corresponding reduction in foliage injury results, that accordingly fewer eggs will be deposited by the adults, and that, in turn, this would be followed by a reduction in tuber injury.

Table 4. *Flea Beetle Injury* on Potato Leaflets Protected by Dusting or Spraying.* Samples Taken July 27 and August 7, 1931

Material	Total of leaf injury	Number of leaflets scored	Average per leaflet	Comparative rating
4% Nicotine dust	8507	372	22.87—	12
Sodium fluosilicate and lime (1-4)	338	280	1.21—	1
Noxum dust (Ferrous carbonate)	698	368	1.90—	2
Barium fluosilicate (Dutox) and lime (1-4)	993	322	3.12—	3
Bordeaux (4-4-50)	4185	306	13.68—	10
Bordeaux (4-8-50) and Dutox (barium fluosilicate) 1½ lbs.	3513	321	10.94+	8
Bordeaux (4-8-50) and sodium fluosilicate 1½ lbs.	3904	345	11.32—	9
Bordeaux (4-4-50) and basic lead arsenate 1½ lbs.	8148	333	24.47—	13
Bordeaux (4-4-50) and calcium arsenate 1½ lbs.	1012	203	4.99—	5
Dutox (barium fluosilicate) 1½ lbs. and water - 50 gal.	1416	353	4.01+	4
Sodium fluosilicate 1½ lbs. and water - 50 gal.	2924	281	9.20—	7
Calcium arsenate 1½ lbs. and water - 50 gal.	3007	357	8.42+	6
Basic lead arsenate 1½ lbs. and water - 50 gal.	11,828	332	35.63—	15
Evergreen (1-100)	9,507	329	28.90—	14
Red Arrow (1-560)	7,291	339	21.51—	11
Pyrethrol (1-100)	9,926	299	33.97	16
Check	24,535	351	69.90	

The insecticide experiments conducted in 1932 included a greater number of chemicals and various dilutions of these materials when used in dust form. The plots used for the work consisted of eight rows 21 feet long, planted May 1, at Brady, in Grays Harbor county. (See Fig. 13.) Seven applications of the insecticides were made at 10-day intervals, starting June 18 and ending August 17. The results were determined by recording the number of larval exit and entrance holes on the tubers and the length of the surface channels. After con-

Fig. 13. Potato flea beetle insecticide plots, Brady, Wash. 1932.

Pyrethrum and Nicotine Sulphate. The pyrethrum sprays and nicotine sulphate failed to give any appreciable protection to the foliage or tubers. Both act as contact insecticides, and no residue remains on the foliage which is toxic to the beetles for any considerable period. Even though the pyrethrums were particularly effective when the beetles came in actual contact with the spray material, such a small percentage was affected that there was really no control. The tubers from the plots that received nine applications of pyrethrum were injured about as much as those in the check plot.

Bordeaux Mixture 4-4-50. Bordeaux mixture, which serves as a repellent to flea beetles, has been one of the standard recommendations for many years in eastern United States. In the experimental plots with Bordeaux, tuber injury was not reduced to the same degree as foliage injury. In the 1931 spray plots, foliage injury was reduced 80.4 per cent, while tuber injury was reduced 67.0 per cent. In 1932, with a lighter infestation of flea beetles, foliage injury was reduced 59.8 per cent, while the tuber injury was reduced 37.1 per cent.

This merely illustrates that Bordeaux has more value in repelling the adult flea beetles which in turn caused a reduction in the amount of foliage injury. The flea beetles oviposit in these plots to a less extent and were not entirely repelled from the plants. Eggs were deposited around the base of the plants regardless of whether the plants were sprayed or not. The results of the tests showed that where Bordeaux was used alone it was not a satisfactory control under western Washington conditions.

Calcium arsenate added to Bordeaux was the most effective of the combination treatments. In this case the efficiency of both materials was increased.

Arsenicals. Arsenicals were used in the form of calcium arsenate, acid lead arsenate, basic lead arsenate, magnesium arsenate, zinc arsenite, and Paris Green. The best control was obtained with calcium arsenate and acid lead arsenate, used as a dust and diluted with lime at a proportion of one part of the arsenical to four parts of lime by weight. Calcium arsenate proved to be the most effective arsenical compound when used either as a dust, spray, or in combination with Bordeaux.

Lead arsenate used in the acid and basic forms gave distinctly different results. The basic lead arsenate did not give adequate protection either to foliage or tubers. When used as a spray at the strength of one and one-half pounds to 50 gallons of water on foliage at 10-day intervals it gave 41.5 per cent control over tuber injury. The same treatment with acid lead arsenate resulted in 67.0 per cent control. Acid lead arsenate was also more effective than basic lead arsenate when used as a dust.

Fluorine Compounds. Sodium fluosilicate, barium fluosilicate (Dutox), and sodium aluminum fluoride (cryolite) were used as sprays, as dusts, and in combination with Bordeaux mixture. When used as a dust the carriers selected were either hydrated lime or diatomaceous silica.

According to the work of Carter (2), the combination of lime and the fluosilicates is incompatible. That is, there is a chemical reaction between the two materials which reduces the insecticidal value. The only carrier used with the fluosilicates in 1931 was lime, and these plots showed the highest degree of control. In 1932 the inert carrier, diatomaceous silica, was substituted for the hydrated lime. Some plots with lime were retained as checks. It was interesting to note that 85.75 per cent control over tuber injury was obtained with lime and sodium fluosilicate. When diatomaceous silica was substitued for the lime, 86.2 per cent control was obtained. This would indicate that any incompatibility of the two materials was not sufficiently great to destroy the insecticidal value of the sodium fluosilicate.

Even though cryolite and sodium fluosilicate gave results superior to barium fluosilicate, they cannot be recommended for use on potatoes in western Washington because of serious injury to foliage. This burning of the foliage obtained with cryolite is not apparently characteristic of the insecticide in other sections of the country. In consideration of this foliage injury the only fluorine compound recommended for use on potatoes in western Washington is barium fluosilicate (Dutox).

Soil Fumigants. Crude napthalene flakes and paradichlorobenzene were used as repellents and soil fumigants. A single treatment was made on June 28, when they were applied in furrows approximately five inches from the plants. These furrows were closed after the material had been placed in them.

When comparing the treated with the untreated plots the amount of tuber injury was reduced 38.6 per cent on the napthalene plot and 34.8 per cent on the paradichlorobenzene plot. Neither material caused any noticeable injury to the potato plants.

A commercial product for the control of subterranean insects sold in the Northwest under the trade name of Pest Foe failed to give any protection to tubers.

Dust vs. Sprays. When the same materials were used in both, the liquid and the dust form, the dusts proved to be more effective. Flea beetles are apparently repelled to a certain degree by poisons sprayed on the foliage. In addition, they probably do not consume sufficient poison to cause a fatal dose. It has also been noted that they will often feed on portions of the leaf surface which have not been covered thoroughly with spray materials.

The effectiveness of the dust may also be explained by the natural "clean-up" habit belonging to this group of insects, as described by Mote, Wilcox, and Davis (8). It has been noted that there is a natural habit of flea beetles to clean their appendages with their mouthparts when any foreign material lodges on them. A flea beetle landing and moving about on dusted potato foliage will get a certain amount of this dust upon its appendages. This will set up a stimulus to remove the foreign particles, especially from its antennae, legs, and mouthparts. In removing the poison with its mouthparts, a sufficient amount may be consumed to constitute a fatal dose.

In 1931, when used as a spray, sodium fluosilicate resulted in 7.6 times as much foliage injury as when this same material was used as a dust. Barium fluosilicate did not show as great a variation, although there was 2.6 times as much foliage injury in the sprayed plot as in the dusted plot.

Control Recommendations

Early Potatoes. Early potatoes should be planted no later than April 19 and during early March if possible. The purpose of early planting is to obtain as much growth and tuber development as possible before the beetles leave hibernation and deposit their eggs near the base of the plants.

As shown by Figure 8, most of the tuber injury takes place after July 8. Potatoes that are not ready for harvesting by July 8 should be protected by using either a calcium arsenate-lime dust (1-4)[1] or barium fluosilicate (Dutox) diatomaceous silica dust (1-1)[2]. The first dusting may be limited to the outer rows in plantings of one acre or more, since the initial infection is limited to the outer edges. The application may be repeated at 10- to 14-day intervals, dusting the entire planting as soon as the infestation is general.

Late Potatoes. Late potatoes should be planted in the period of June 15 to July 15. Potatoes planted in that interval developed tubers which were relatively free of tuber damage without the use of any insecticide. Added protection may be obtained by dusting the plants after they start to grow. When Bordeaux (4-4-50) is used as a fungicide, one and one-half pounds of calcium arsenate should be added for flea beetle control.

In districts troubled with the potato flea beetle no potatoes should be planted in the period from April 19 to June 1.

Summary

1. An epidemic of potato flea beetles has occurred in parts of western Washington since 1925. The injury was periodical until the appearance of the potato flea beetle, *Epitrix cucumeris,* of the eastern United States.

2. The larvae of the western potato flea beetle, *Epitrix subcrinita,* caused tuber injury under insectary conditions. It has never been as serious a pest in the field.

3. In Washington there is one generation and a partial second generation annually. The overwintering adults emerge from hibernation during May and June.

4. The majority of the adults of the new generation emerge from the ground in the period from July 25 to August 17.

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[1] One part calcium arsenate to four parts of hydrated lime by weight.

[2] One part barium fluosilicate to one part of diatomaceous silica by weight.

5. A gradual increase in the number of adult flea beetles occurs in the potato field throughout June and in the early part of July, a rapid increase occurs in late July and early August and a decline starts around August 25 and continues throughout September and October. Complete disappearance takes place in early November.

6. Accompanied by the increase of the flea beetle population is a greater amount of injury on the potato foliage. Under heavy infesta tion, plants may be killed during August. The greatest amount tuber injury occurred on those potatoes planted in the period fr April 19 to June 1.

7. Most of the larval injury on the tubers is accomplished duri the latter part of July.

8. Rhizoctonia and scab become more serious with the flea b injury. Crop rotation and seed treatment are even more ess under these conditions.

9. Eight varieties of potatoes grown under the same field cor tions showed a variation in the amount of injury on the tubers. C Coin had the least injury, while Beauty Hebron was the most seve affected.

10. The most efficient insecticides for flea beetles were dusts composed of calcium arsenate and lime (1-4) and barium fluosilicate and diatomaceous silica (1-1).

11. Bordeaux mixture and calcium arsenate were the most effectiv combination that included an arsenical poison.

LITERATURE CITED

Cameron, Alfred E. Control of the Potato Flea Beetle. Rept. N. J. Agr. Col. Exp. Sta. 1914: 375-381. 1915.

Carter, R. L. The Incompatability of Lime with the Fluosilicates. Jour. Econ. Ent. 24: 263-268. 1931.

Forbes, S. A. The Potato Flea Beetle. Rept. Ill. State Entom. 21: 117. 1900.

Harry L. Arsenicals in Potato Flea Beetle Control. Ohio \gr. Exp. Sta. Mon. Bul. 156: 104-111. 1932.

ıer, J. L. and Gillette, C. P. The Potato Flea Beetle. Colo. Agr. Exp. Sta. Bul. 337: 1-20. 1928.

:tt, H. H. Potato Flea Beetles. Ky. Agr. Exp. Sta. Bul. 297: ?83-301. 1929.

ısen, O. A. Potato Flea Beetle. Maine Agr. Exp. Sta. Bul. 1: 37-50. 1913.

Don C. Wilcox, J. and Davis, E. G., The Natural Clean-up Habits of Insects. Jour. Econ. Ent. 19: 745-748. 1926.

llan, H. G. and Schaal, L. A. A Pathological Feature of Flea 3eetle Injury on Potato Tubers. Jour. Agr. Res. 39: 807-815. 929.

;tewart, F. C. The Cucumber Flea Beetle as the Cause of "Pimply Potatoes." N. Y. Agr. Exp. Sta. Bul. 113: 311-317. 1896.

Vebster, R. L. Potato Insects. Iowa Agr. Exp. Sta. Bul. 155: 367-375. 1915.

———, Injury and Distribution of the Potato Flea Beetle in Washington. Jour. Econ. Ent. 25: 976-980. 1932.

———, Baker, W. W., and Hanson, Arthur J. Potato Flea Beetles in Washington. Wash Agr. Exp. Sta. Bul. 261: 1-20. 1932.

FORAGE CROPS FOR CENTRAL WASHINGTON

A Review of Experiments under Semi-Arid Conditions on The Adams Branch Experiment Station

by
H. M. Wanser

Introduction

Forage crops have an important place on the dry land farms of central Washington. The census data of the five counties, Adams, Douglas, Franklin, Grant, and Lincoln, show that one acre of hay is harvested for every 10 acres of wheat and that there are two acres of pasture for every three acres of crop land or approximately two acres of pasture for every one and one-half acres of wheat. In recent years there has been a decrease in the acreage of crops cut for hay, but there has been a large increase in the acreage listed as pasture. Between 1924 and 1929 the increase in pasture amounted to 39.6 per cent. There were 1,737,895 acres in pastures in the five counties in 1929.

The increase in the area used for pasture and the decrease in acreage of crops cut for hay have several causes. The replacement of work stock by tractors is one of them. Another contributing factor is that farmers have let stock graze more of their own feed from pastures to eliminate the expense of harvesting the required forage as hay.

Evidently a return to pasture crops and grazing is expedient on lands that no longer can be made to produce cultivated crops under the summer fallow system. Soil investigations have shown that cultivation and cropping by the summer fallow system have depleted the fertility of the surface soil. Recent soil studies from the viewpoint of erosion by both wind and water have suggested that cultivation of the drier areas and the farming of them by the summer fallow system cannot be continued indefinitely. Permanent rooted pasture crops which do not require stirring of the surface do not deplete but increase the soil fertility and tend to prevent both wind and water erosion. Therefore the interest in pasture crops may be exepected to increase in the future.

The production of harvestable forage and fodder is a more difficult problem on the drier areas of central Washington than it is under the more favorable conditions in the sub-humid areas surrounding them. Moisture is the chief limiting factor in crop production, and before a crop with sufficient tonnage or height for harvesting can be produced it is necessary that the moisture supply for the current crop growing season be supplemented with a part of the moisture supply received during the preceding season. The summer fallow system does this and has made possible the production of grain crops under semi-arid conditions.

The summer fallow system permits a crop on any area in alternate years only. Crops grown annually, whether from perennial root systems or from annual sowings, are severely handicapped by moisture shortage and can not be expected to equal, either in height or yield, the crop on areas alternating with fallow. To get crops large enough *to harvest they must be raised on fallow.* This fact is well recognized in grain farming but is often forgotten in forage production. Wheat and rye have proved their superiority as crops in such areas, and the production of hay and straw from them has seemed to be the most promising solution of the harvestable forage problem.

Such a solution is a logical procedure and is well suited to present farming practices and equipment. In growing wheat for grain the borders and roadways which are sown as a part of the main field very largely have been lost when left until the grain was harvested and then trampled over in the first round by the "combine" harvester. To save the borders and roadways, the fields have been trimmed up with a binder, header, or mower before maturity and the trimmings used for hay. On a majority of dry land farms these trimmings have constituted the entire hay crop harvested. According to the last census the cereal crops form 86 per cent of the total hay crop of the five counties and they probably form all the hay crop on the dry land farms.

The maintenance of a supply of green feed for summer pasture is even more difficult in the dry farm areas than is the production of harvestable forage. The humid winters and arid summers definitely limit the amount of green growth that can be made and the type of plant making it at any season. Early growing perennials, winter annuals, and frost hardy plants take advantage of the moist early spring growing season. Summer growing and late maturing plants suffer from drought during the summer season for no plant remains green all season without moisture.

Many different kinds and varieties of crops that are often raised for forage purposes have been tried at different times on the Adams Station. The experiences and results gained in making these trials form the basis of this bulletin.

Location and Establishment of Station

The Adams Branch Experiment Station was established in the fall of 1915 in order that the agronomic phases of dry farming might be studied. The original agreement specified that it be located west of Range 34 and south of Township 19 with the general understanding that such a location would put the Station so far into the arid sections that yields obtained from field crops would not have been favored by location but would be representative of a large area The Station farm lies on rolling hill land bordering the large Lind coulee and about three miles northeast of the town of Lind. Many thousand acres in central Washington have climate, soil, and topography similar to that on the Station, yet the Station is not far from the fringe of the driest area that produces crops with any degree of assurance and regularity.

Climatic Factors

Forage as well as all crop production is very much dependent on favorable climatic environment. Certain features usually are unfavorable under dry farm conditions, and not being controllable they tend to limit production. On the Adams Station the low average amount of annual precipitation, its particular and relatively poor distribution, and the association of favorable growing season temperatures with periods of diminishing soil moisture are the limiting factors of most importance.

The limited amount, poor distribution, and variable nature of the precipitation are partly indicated in Figure 1, which shows the precipitation by monthly intervals for individual crop years September 1 to August 31, in comparison with the average for 15 years. During the period covered by these data the annual precipitation has averaged only 7.88 inches. By crop years it has varied from a low of 4.80 inches for the crop season of 1930 to a high of 12.65 inches for the crop season of 1927 and has been less than 7.00 inches in half the years.

Most of the precipitation comes during the late fall, winter, and early spring, July and August being nearly rainless. About 24 per cent of the rainfall comes during the growing season and the amount has varied from 5.27 inches in 1923 to 0.37 inches in 1924. On the average the precipitation during the growing season has been received in about 14 rains, but only three of them have amounted to more than 0.20 inches or have been of sufficient size to wet through the seed bed. The average total of these three effective rains, that is, the ones which wet through the seed bed, has amounted to 1.19 inches. However, this amount is actually received in effective rains in only about one-third of the growing seasons. In another third of the growing seasons

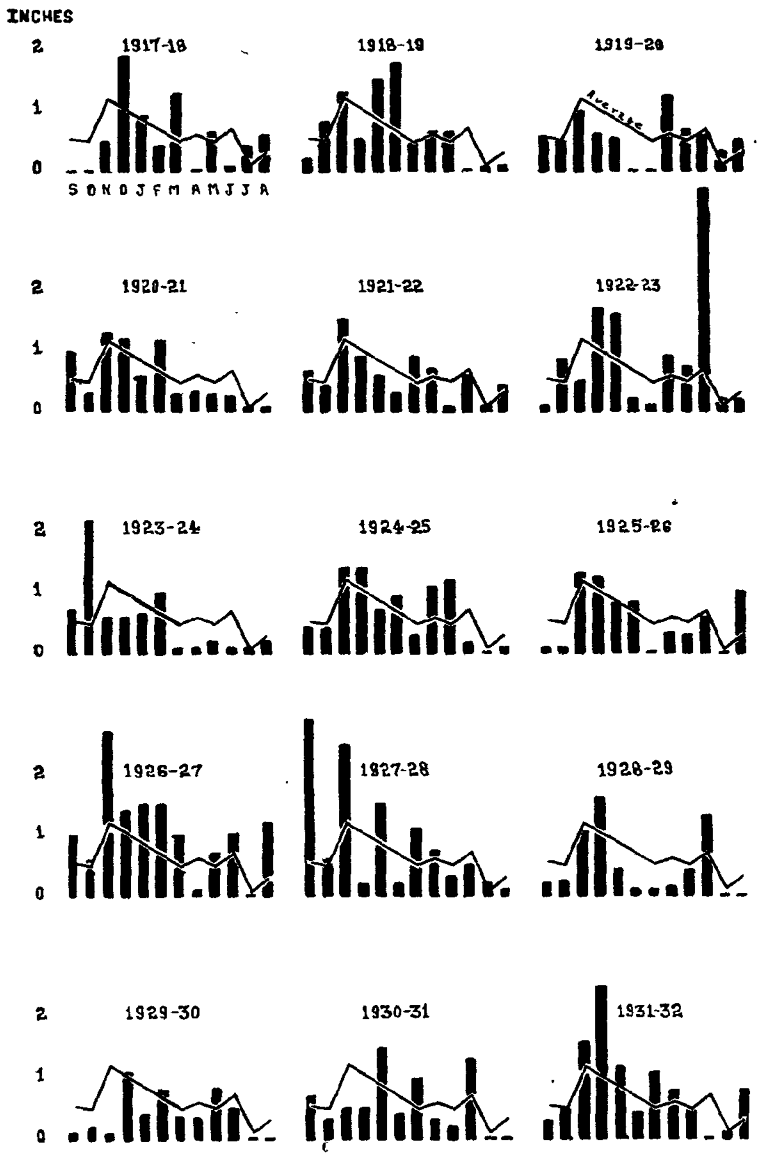


Figure 1. The precipitation by months for the crop years Sept. 1 to August 31 from 1917 to 1932 in comparison with the average for the period.

there are no rains heavy enough during April and May to wet the seed bed through, and long intervals without effective rains occur every season.

Figure 1 also shows that only three fall seeding seasons, 1923, 1926, and 1927, have had relatively abundant rainfall and that only two seasons, 1923 and 1925, have had relatively abundant rainfall during the spring growing season. Thus the probabilities of favorable moisture for fall seeding or of favorable moisture for prolonged or delayed spring seeding have been about one in five. In general the data in Figure 1 show that the precipitation is extremely light, quite variable in amount, and irregular in season. It is dependable only for early spring seeding and is not dependable for seeding regularly at any other time.

Supplies of soil moisture have varied almost as much as the precipitation although, because of runoff and temperature influences, not always in the same ratios. The amount of moisture available to plants at the beginning of the spring growing season has varied from the equivalent of 1.47 inches to 5.54 inches of precipitation. For each foot in depth that the soil has been moist at the opening of spring it has held the equivalent of from 1 to 1.25 inches of precipitation, and in general the greater the moisture supplies the deeper the soil was moist. Fallow the previous season has added the equivalent of from 0.63 inches to 2.82 inches of water to the moisture supply available without fallow, and has increased the depth of moisture in the soil acccordingly. In only one season in five has sufficient rainfall occurred after the spring growing season started to increase the supplies of soil moisture.

The length of the growing season has been partly determined by the depth of soil moisture at the opening of spring. In general the moisture from about one foot of soil is exhausted for each month the growing season advances. Although the rate of use generally increases as the season advances, the deeper the wet soil extended the longer the growing season lasted.

Other conditions which determine the extent of the growing season are shown in the data of Table 1 which gives the average and extreme dates for certain seasonal conditions and operations over a 14-year period. Although not shown in the table because comparable data were not available, perennial crops and crops on areas not fallowed always ripen or dry up at an earlier date than the ripening date for spring wheat. Many perennial and winter annual crops also start spring growth earlier than the emergence date for spring wheat. The data of Table 1 show that the average length of growing season for spring sown crops has been about 104 days and that the first 45 days are subject to frost and hence not "available" for growing frost-tender plants.

Table 1. Average and extreme dates on which seasonal conditions, operations, and behavior of spring wheat occurred from 1918 to 1932 inclusive

Condition or operation	Average	Extremes	
		Early	Late
First fall freeze up	Nov. 17	Nov. 1	Dec. 5
Frost leaves ground in spring	Feb. 17	Jan. 27	Mar. 5
First spring seeding (wheat)	Mar. 7	Feb. 18	Mar. 19
Emergence of first spring seeding	Mar. 30	Mar. 16	Apr. 10
Late frost in spring	May 13	Apr. 26	May 27
Heading of spring wheat	June 4	May 26	June 16
Ripening of spring wheat	July 11	June 30	July 26
		Shortest	Longest
Days between emergence of first spring seeding and last frost in spring	44	27	70
Days between last frost and maturity of spring wheat	60	36	79
Length of growing season in days	104	92	112

The foregoing discussion of climatic features has been presented to show that spring opens and the growing season starts with a blanket of moist soil which always dries out as the season advances. The chances that the soil moisture supply will be added to or that the seed bed will be wetted through after the season starts are not very great and they diminish as the season advances. The growing season ends when the soil moisture has become exhausted in midsummer. The seed-bed moisture and some subsurface moisture always dry out, whether or not the soil is supporting plant growth. The growing season for perennial, winter annual, and frost-hardy plants starts earlier and therefore covers a greater period than does the growing season for frost-tender plants because moisture is the limiting factor for the growth of all plants and they exhaust it about the same time in midsummer.

Small Grain Cereals for Forage

The small grain cereals are more frequently thought of as cash grain crops than as forage crops, but as previously explained most of the hay on the dry farms is cut from the small grain cereals. They more nearly fit the characteristics of an ideal forage crop on cultivated

land than other crops, that is, they more nearly meet the climatic and farming scheme limitations. They start growth in the early spring. They make a rapid growth while the soil moisture is most plentiful, and even though it be limited they usually mature a crop by the time it has become exhausted. They also fit the farming scheme of alternate crop and fallow. They are the principal crop of the dry farms, and can be grown and harvested for hay with small adjustments or additions to field equipment already used in growing them for grain. When the small grain cereals, usually wheat, are grown for both principal grain crop and home hay needs the areas required to provide sufficient hay can easily be adjusted to compensate for fluctuating yields by increasing or decreasing the areas cut. In addition to these qualifications the small grain cereals have produced harvestable yields more consistently than any other crop tried, and they therefore merit classification as forage crops on cultivated areas for the dry land farms.

The small grain cereals have been grown primarily for grain yield in the cereal investigations on the Station. They have been grown in one-twentieth and one-fortieth acre plats with two to four replications each season. In harvesting the crops a short stubble of five inches or less has been left, and the total air dry weight of the mature crop before threshing has been recorded as the forage yield. Grain and straw yields have been obtained from the same crop after threshing. Cereal hay usually is harvested before complete maturity, but in dry farm practice it is generally allowed to become more nearly mature than it is in the humid sections. The comparative yield and merits of the different varieties of any cereal or of the different kinds of cereals are not altered greatly by growth between the dry farm hay stage and complete maturity; therefore the data at complete maturity have been taken as representative of forage yields.

Ten different kinds and many varieties of cereals have been grown at different times in field plats and the total forage harvested. The varieties grown have included 11 varieties of winter rye, seven varieties of spring rye, 74 varieties of winter wheat, 118 varieties of spring wheat, three varieties of winter barley, 11 varieties of spring barley, 13 varieties of oats, and one variety each of red winter spelt, black winter emmer, and white spring emmer. The yields of the spelt, emmers, and winter barley were so poor that they were not grown after a few trials. The annual yields of forage from 1924 to 1932 are given in Table 2. Some cereals show better in comparisons of poor yield years; therefore the averages in Table 2 are calculated in two periods. The yields were good for the period from 1925 to 1928 and poor for the period 1929 to 1932.

More forage has been harvested from winter rye than from any of the other cereals, and on the basis of total yield alone it should be

the cereal recommended for hay. The growth of winter rye in a favorable season is shown in Figure 2. When left until nearly mature before harvesting, however, winter rye makes rather coarse hay. It is

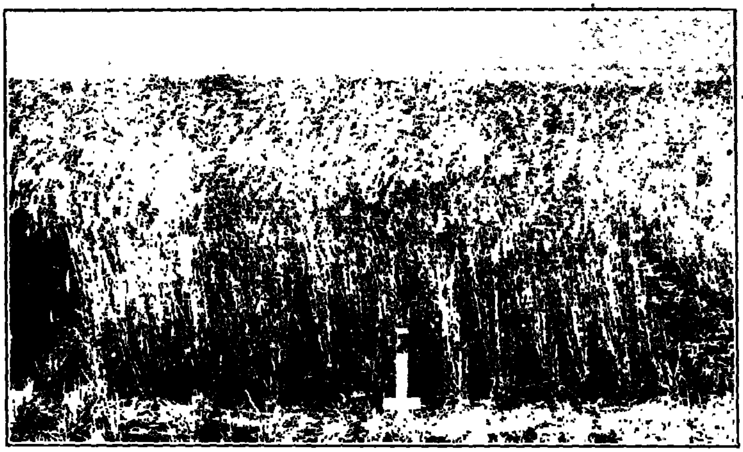


Figure 2. Winter Rye on July 10, 1927. Yield of forage 3590 pounds per acre. Height 4 feet.

not well liked by stock at certain stages of growth, particularly at the jointing stage when it seems to have an undesirable flavor and stock seem to prefer almost any other green feed. Winter rye grows at cooler temperatures than the other cereals, and will furnish pasturage at an earlier date in the spring. It sometimes matures too early to make full use of summer rains. The comparative yields of spring wheat and winter rye for 1929 and 1932 given in Table 2 show the better response of spring wheat to late rains. Winter rye has been the most valuable cereal for "stubbling in" and raising crops continuously on the same cultivated area. In the nine-year period from 1924 to 1932 the annual forage yield of winter rye when grown continuously has been just half the annual yield from alternate crop and fallow. The average annual forage yield from winter wheat and spring wheat grown continuously has been 47 and 45 per cent of the yield from alternate crop and fallow areas. Thus total yields from an area are sacrificed when wheat is grown continuously rather than alternately, but are not sacrificed when winter rye is grown continuously. Therefore, winter rye is better for "stubbling in" continuously. Rosen rye has given larger yields than any of the other 11 varieties of winter rye tried on the Station. Stands of winter rye have been obtained every year although some years they have been poor.

Table 3. Annual and average yields of air-dry forage in pounds per acre from several miscellaneous crops in comparison with average forage yields of wheat for same years

Crop	Pounds forage per acre									Average forage yield of wheat for same years	
	1919	1920	1924	1925	1926	1927	1928	1932	Average	Spring	Winter
Sunflowers											
Green weight	10000	9800	—	—	—	6420	—	5670	7970	—	—
Dry weight	1725	1690	—	—	—	1090	—	1135	1410	1605	1925
Sweet clover											
One-year stand	—	—	—	760	168	—	—	—	—	—	—
Two-year stand	1500	—	—	1820	+400*	2540	—	—	1865	1960	1905
Alfalfa	700	880	740	200	780	1930	895	—	875	1795	2275
Crested wheat grass	—	—	—	350	—	1430	—	400	725	1990	1610

* This yield was high because of favored location receiving drainage from barnyard

More forage has been harvested from winter wheat than from any of the other cereals except winter rye, when the seasons have been favorable to the growth of winter wheat. However, favorable seasons have not come regularly and winter wheat has not been a dependable crop for forage production. It is, however, better liked by stock than winter rye. Beardless types of winter wheat such as Jones Fife or Ridit are often sown for cereal hay in preference to the bearded varieties which are sown for grain. In trials of pasturing stubble and in feeding forage from a manger, stock have always shown a preference for the Turkey types of winter wheat. They seem to prefer the finer and apparently more palatable straw of the Turkey or Crimean type of wheat. The yields of Turkey winter wheat are given in Table 2. This variety has higher grain yields and as good forage yields as any of the 74 varieties of winter wheat tried.

The yields of forage from spring wheat have not been quite as large as from winter wheat or rye, but spring wheat can be grown when those crops winter kill. It is therefore the most dependable crop for the production of forage in adverse seasons. An average crop of spring wheat is shown in Figure 3. Larger yields of grain have

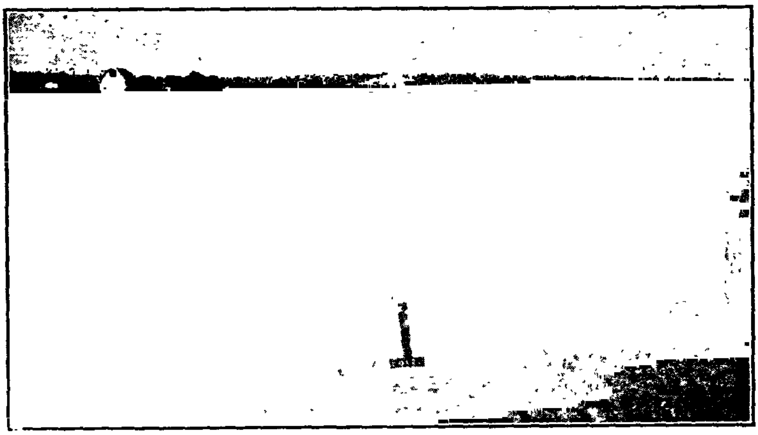


Figure 3. Baart spring wheat on July 2, 1932. Forage yield 1705 pounds per acre, an average crop. Height 20 inches. Spring wheat can be grown more consistently than any other crop. Feeding trials show stocks do not object to beards, and Baart is the recommended variety for both forage and grain.

been obtained from Baart than from the other spring wheat varieties, and also in low yield seasons more forage has been obtained from this variety. When the spring season opens especially early and is unusually long, as in 1924, more forage may sometimes be ob-

tained from longer strawed varieties such as Pacific Bluestem than from Baart. In feeding trials with forage from spring wheats work stock have shown no preference for any particular variety tried. Neither have they shown any particular dislike for bearded varieties. In the feeding trials it has been noticed that stock with mouths that were tender and had wrinkled interiors become "bearded" more easily than stock with tougher and smoother mouths.

The yield of forage from barley has been slightly less than from spring wheat in good seasons and much less in poor seasons. The yield of forage from oats has been less than from spring wheat and barley in practically all seasons. Both barley and oats have nearly always been more difficult to harvest than spring wheat as they lean over at or near maturity more frequently than wheat. Barley has often had weak or partially developed crown roots and has been poorly supported, and oats has had weak straw which bent over easily at and after maturity. Both barley and oats have been blown over easily when strong winds occurred before the crops could be harvested.

Results with the small grain cereals show that they are the best crops for harvestable forage for the dry lands. They merit consideration and are recommended. When winter wheat and rye cannot be grown spring wheat should be sown.

Annual Legumes

Legumes are desirable as supplemental crops to provide the necessary protein balance in feeds where most of the forage has been obtained from the cereals. Annual legumes fit into the alternate crop and fallow farming system and have been tried out as harvestable forage. The varieties and strains grown on the Adams Station have included 15 varieties of field peas, 12 varieties and strains of vetches, 20 varieties and strains each of chick peas and soy beans, and several varieties of field beans. The soy beans, field beans, and chick peas were all so poor that they were not grown after a few trials. Several varieties of field peas have been of about equal value for the production of seed peas, but for forage production the Kaiser variety has been most promising. The yields of forage harvested from this variety are given in Table 2 for comparison with the cereals. Early experiments showed that the best method of growing field peas was to sow them in double rows spaced seven and 28 inches apart and to cultivate at least once during the growing season for weed control. The method of growing field peas is shown in Figure 4. When left until near maturity before harvest pea hay has had coarse woody stems which have not been liked by stock and the seed peas themselves, under dry conditions, become so hard that the stock cannot eat them until they are softened by soaking. The pea crop has usually been more weedy

with thistles than the cereal crops, and the forage from peas has been less desirable for that reason.

Figure 4. Kaiser peas June 23, 1932. Sown in double rows 28 inches apart and cultivated once during growing season. Yield of forage 1210 pounds per acre.

Hairy vetch (*Vica villosa*) has been much finer stemmed than field peas, and has been well liked by stock even when the crop was allowed to become mature before being harvested. Hairy vetch has shattered easily in the riper stages especially when the ripe or nearly ripe crop has been wet by showers. The shattered seed tends to come up as a volunteer crop the next season and assume weed characteristics. Under dry land conditions the volunteer from hairy vetch has bothered very little and has been choked out easily by the first crop of wheat following. Hairy vetch is shown in Figure 5. It has been difficult to harvest clean hay from peas and vetch since the plants of both trail close to the ground when sown alone and many clods are picked up in harvesting. Both peas and vetch are choked out when sown with the cereals under dry land conditions. Both hairy vetch and field peas are frost hardy, and should be sown very early in the spring, even before seeding spring wheat so they can take advantage of the cool, early spring, growing season.

Miscellaneous Crops for Forage

Miscellaneous crops grown in field plats for forage trials have included nine varieties of corn, 17 varieties of sorghum including feterita, broom corn, and Sudan grass, and also rape, sunflowers, arti-

Figure 5. Hairy vetch June 4, 1926. Yield of forage 1300 pounds per acre. This crop matured earlier than wheat and a small shower at maturity caused much of the seed to shatter out before it could be harvested.

chokes, millet, Lespedeza, and Russian thistles. Most of these crops are not frost hardy and cannot be sown until danger of frost has passed, which under central Washington dry land conditions usually means that they cannot be sown until after the first third of the growing season has passed and after the seed bed has become dried out and the soil moisture supply partly lost by evaporation. Most of them are late maturing summer growing plants, and because they

Figure 6. Sunflowers July 8, 1927. Yield of green feed 6420 pounds per acre, equivalent to 1090 pounds fodder. Height 36 inches.

Table 2. Comparative annual and average yield in pounds per acre of forage from various small grain cereals and coarse-seeded annual legumes. 1924-1932

Crop	Variety	Pounds per acre of forage									Average	
		1924	1925	1926	1927	1928	1929	1930	1931	1932	1925 to 1928	1929 to 1932
Winter rye	Rosen	3375	895	2500	3590	5900	1455	1060	940	1055	3221	1127
Winter rye*	Minn. No. 2	2430	—	630	2180	1420	220	360	500	1060	—	535
Spring rye*	Station	1080	1770	760	1200	520	320	240	420	780	1062	440
Winter wheat	Turkey	1785	1935	2225	3940	4230	—	—	730	815	3082	—
Spring wheat	Baart	1210	2285	1970	1975	2380	1550	835	480	1705	2152	1142
Spring wheat	Bluestem	1580	2200	1815	1990	2470	1590	540	610	1605	2119	1086
Barley	Meloy	945	2250	1830	1330	2500	1395	460	410	1210	1977	869
Oats	Markton	870	1570	1440	1640	2680	1140	460	390	1290	1832	820.
Peas	Kaiser	800	2720	1440	1720	2405	1510†	1495†	1680†	1210	2071	1474
Hairy vetch												
Winter sown	—	—	—	1300	2980	2865	—	—	—	—	—	—
Spring sown	—	—	—	—	760	3620	1335	1175	455	1420	—	1096

* These crops ''stubbled in'' continuously. All other crops were grown on summer fallow.
†.These yields high because of favored field location and weedy condition of crop.

suffer from drought the yields have been poor. Except for sunflowers, they have not been grown after a few trials. The thistles are tender or palatable only in the early stages and have not shown merit as a harvestable crop.

Sunflowers and corn and similar large seeded plants which are usually sown in hills or in thin stands have been so badly eaten and carried away by pocket field mice that the stands have been ruined many times. Several deterrents tried have not prevented the damage. Damaged stands have had to be resown and the resowing has always been in a drier seed bed. Sunflowers have been harvested four years although they have been sown several other seasons without harvesting because of too poor stands and yields. Sunflowers sown with a grain drill are shown in Figure 6. The stand of plants was too thick for the amount of available moisture and only a few plants bloomed. The yields of sunflowers in comparison with wheat for the seasons in which harvests were obtainable are given in Table 3. Sunflowers are difficult to use on the average dry farm as their main forage value is for silage. They are of questionable value and are not recommended for the dry areas even though good yields are sometimes obtained from them.

Perennial Legumes

Alfalfa and sweet clover have similar characteristics under dry land conditions, and have been tried in field plats with only fair success. Common alfalfa has appeared better than any other of the 14 varieties and strains that have been tried. Method-of-growing trials showed that taller growth and greater percentage of bloom were secured when the alfalfa was sown in rows 24 to 28 inches apart. Because of its perennial root system alfalfa is a continuous crop on any area. Under extreme dry farm conditions it has usually suffered from drought and often has dried up before the first spring growth has reached full height or the blossom stage. Irregular stands have caused variable maturity because the thick parts of the stands dry up before blooming and the thinner parts continue growth for a longer period. It has been difficult to harvest clean hay from the thin stands or from the short crops because of the inclusion of clods, weeds, and dust.

Alfalfa has been harvested seven times and the yields in comparison with wheat for the same years are given in Table 3. The especially low yield of alfalfa in 1925 was caused partly by winter injury to the stands. Yields of alfalfa have been harvestable only in high yield years. In poor years the crop has been too short for harvest.

Stands of alfalfa and sweet clover have been hard to establish. The small seed and slow growing seedling plants require seed beds which retain a moist surface for long periods. Therefore spring seeding has been necessary and good stands have been obtained only when the rainfall for April and May has been well above the average.

Weeds also thrive in favorable seasons, and the stands of alfalfa and sweet clover have always been nearly choked out by the Russian thistles.

Four varieties of sweet clover have been tried. The common biennial white blossomed sweet clover has given best results, but yields of it have been harvestable only in favorable seasons. The hay has been coarse and woody because the stands were thin. The yields of sweet clover for the crops harvested and of wheat for the same years are given in Table 3.

Perennial Grasses

As indicated earlier in this bulletin, grasses are becoming of greater importance for the dry farm areas. There are many thousand acres on the dry farms of central Washington that have produced wheat at one time but that are not now being cultivated for that purpose. Such areas will produce more stock feed when sown to the right kinds of grasses than when abandoned and left to grow only weeds.

Stands of grasses have been maintained all of the 14 years since the Adams Station was established. Very little hay has been harvested from the grass plats. Most of the grasses that seemed adapted have

Figure 7. Slender wheat grass (Agropyron tenerum) **June 13, 1932. This plat was sown in the spring of 1931. The plats of Quincy grass** (Oryzopsis hymenoides) **and native blue grass** (Poa sandbergeii) **in the background were sown in fall of 1931. Only a few seedlings of these grasses survived the crusting of the soil the following spring.**

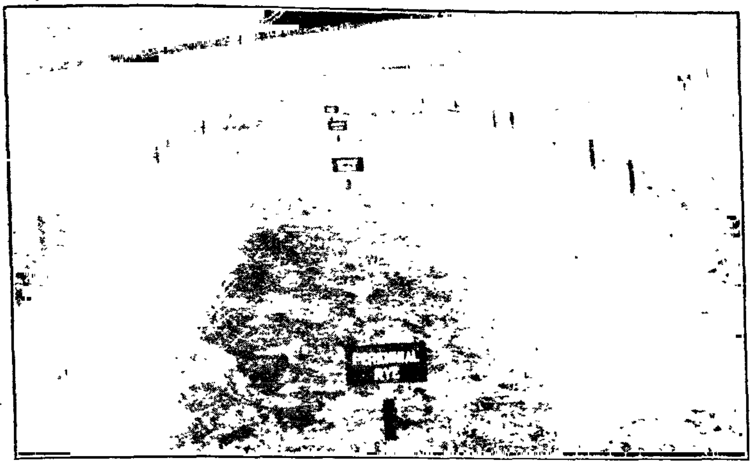


Figure 8. Perennial Rye (Secale montanum) **June 13, 1932. The perennial rye was late in maturing and had not headed when this photograph was taken. It was sown in the spring of 1931. The three plats of Quincy grass** (Oryzopsis **hymenoides) in the background were sown in the spring of 1932, the first two plats were sown very early and the third plat later. Note the poor stand on the third plat.**

shown greater pasture than hay values. In most seasons and especially in low yield seasons a large proportion of the total growth of the grasses has been in the leaf stages below the sickle bar of harvesting machinery. Such growth cannot be harvested by machine but would be available to stock under pasture conditions.

The varieties of grasses tried at different times have included slender wheat grass, *Agropyron tenerum;* crested wheat grass, *Agropyron cristatum; Agropyron spicatum; Agropyron elongatum; Agropyron imbricatum;* awnless brome grass, *Bromus inermis; Bromus pinnatus;* needle and thread grass, *Stipa comata;* Canadian bluegrass, *Poa compressa; Poa sandbergii; Poa bulbosa;* tall meadow oatgrass, *Arrhenatherium elatius;* orchard grass, *Dactylis glomerata;* "Quincy" grass, *Oryzopsis hymenoides;* perennial rye, *Secale montanum;* and *Elymus condensatus*

The grasses of the Poa species have been tried chiefly for sod production. All other grass trials have been intended for both hay and pasture production. Nearly all of them have been disappointingly poor in the production of hay and crested wheat grass is the only variety from which hay has been harvested.

Plats of several grasses are shown in Figures 7 and 8. These photographs show some causes of poor stands in grass seedings

In trials with mixtures of wheat grasses and other grasses, nearly all the surviving stands, after the weed crop is removed, have been wheat grasses. These grasses therefore are found to be better adapted than others. In the trials with mixtures of four wheat grasses the persisting stands after a number of years have been crested wheat grass, and therefore, this particular variety of wheat grass is shown to be longer lived than the other wheat grasses.

Crested wheat grass has been harvested for hay three times, and the yields in comparison with wheat for the same years are given in Table 3. Some hay could have been harvested from it in other years when the yields did not look very promising in comparison with wheat. The harvestable yields of crested wheat grass have been about one-third to one-fourth the yields of wheat for the same years. In especially good years such as 1927 a large proportion of the total yield of crested wheat grass has been above the sickle bar of harvesting machinery, but in other seasons nearly half the yield has been below the sickle bar in the form of basal leaves.

Crested wheat grass is a bunch grass in that it grows in tufts and does not form a continuous sod. The bunch nature of crested wheat grass is shown in Figure 9. Although many small volunteer plants have appeared between the bunches in this stand, they have not survived and the number of bunches has remained practically unchanged. The heads or seed spikes of crested wheat grass are more compact than the heads of other wheat grasses, and compare with others as the club wheats compare with common wheats. Crested wheat grass is hardy and very cold resistant. It did not appear to be

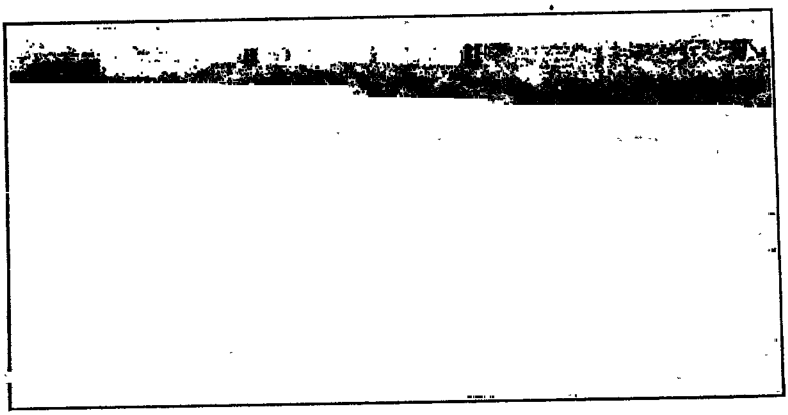


Figure 9. Crested wheat grass (Agropyron cristatum) April 25, 1929. This photograph shows the basal leaves and bunch nature of a four-year-old stand which has been grazed only in alternate years.

injured in the winter of 1924-25 when winter wheat, winter rye, alfalfa, wild mustard, and many other hardy plants were badly injured by a sudden cold snap. It grows at cool temperatures and starts growth as early in the spring as any wild grass and before any of the other cultivated grasses. It can use winter moisture before it is lost by evaporation in spring winds. It dries up in midsummer when the soil moisture becomes exhausted but is revived if summer rains occur. It is well liked by stock.

The best stands of crested wheat grass have been obtained when sown on clean summer fallow, although stands have also been obtained when fall sown in the stubble of fall-sown wheat or rye. It should be sown in the fall if possible. The winter annual weeds the following season have been controlled by mowing when the mustard began to bloom. When sown in the spring and when the seed bed was not unusually well protected from rolling weeds, thistles have nearly choked out and usually thinned the resulting stand. This also happens when sown in the stubble from spring sown wheat. When sown in the spring, two or more years have been required before a stand could be established as the full length of a winter and spring growing season are required for the small seedlings to develop crown roots.

Figure 10. Crested wheat grass (Agropyron cristatum) May 31, 1932. This field was sown in rows 14 inches apart with a grain drill in the fall of 1929 and pastured after maturity in 1931. The yield of recleaned seed in 1932 was 100 pounds per acre. The yield of forage above the sickle bar of the binder harvesting it was about four times the seed. Almost as much forage was left below the sickle bar as was harvested above it. The Station farmstead is in the background.

Crested wheat grass can be sown with the ordinary grain drill and five to 10 pounds of seed are required per acre. About five pounds will be sown per acre when the ordinary grain drill is set in the second notch to seed two and one-half pecks or 37 pounds of wheat per acre and only every other feed cup on a seven-inch drill is allowed to deliver seed. The stand of crested wheat grass shown in Figure 10 was sown by this method.

Stands of crested wheat grass will persist for many years. One stand on the Station still seemed thrifty at the end of 11 years, and when plowed up it was found that it had filled the surface soil with a thick mat of roots.

Crested wheat grass should not be over-grazed because the stock eat the crowns of the plants and thereby deplete the stands. The results of over-grazing are shown in Figure 11. The carrying capacity will vary with the season and prospective crop yield, but should always be equal to one-half that of winter rye grown on fallow. Crested wheat grass is recommended for sowing on areas which were

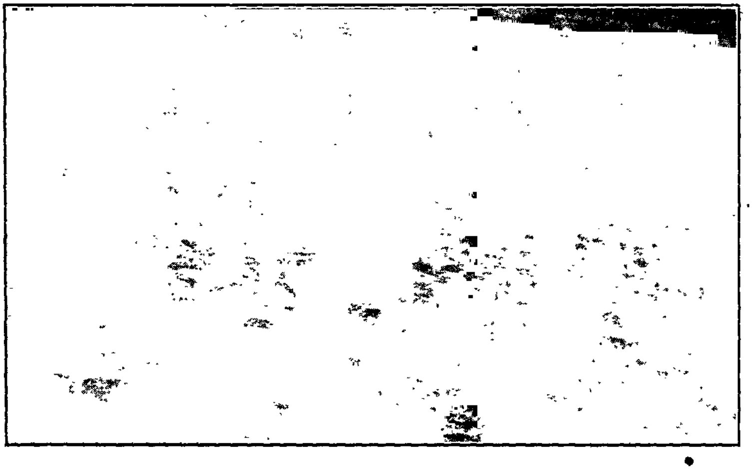


Figure 11. View of a thin stand of crested wheat grass May 23, 1931 showing the stand depleted by over-grazing and encroaching cheat grass (silvery tops).

once cultivated for growing wheat but which have been allowed to grow only weeds in recent years and on which grass would be more desirable.

Quincy grass (*Oryzopsis hymenoides*) or Indian mountain rice, as it is sometimes called, has been sown on the Station several times in both fall and spring. Very poor stands were obtained from the first

STATE COLLEGE OF WASHINGTON

AGRICULTURAL EXPERIMENT STATION

Pullman, Washington

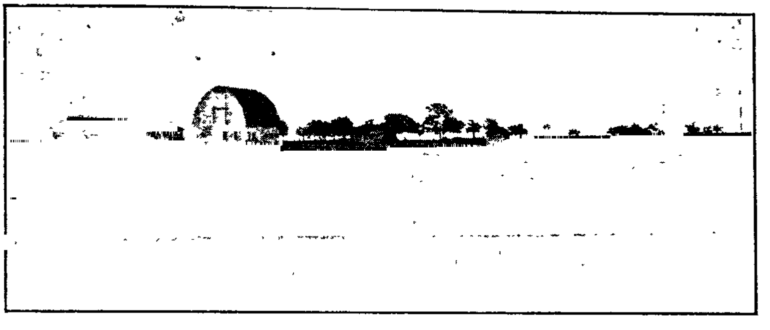
Adams Branch Experiment Station

Lind, Washington

Forage Crops for Central Washington

by

H. M. Wanser



Bulletin No. 281

July, 1933

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F. L. Overley, M.S, Associate in Horticulture, Wenatchee.
J. W. C. Anderson, M.S., Asst. Horticulturist.
L. L. Claypool, B.S., Asst. Horticulturist, Irrigation Branch Station, Prosser.
Kenneth A. McKenzie, M.S., Assistant in Horticulture, Wenatchee.
C. D. Schwartze, B.S., Research Assistant.

Plant Pathology

F. D. Heald, Ph.D., Plant Pathologist in Charge.
L. K. Jones, Ph.D., Assoc. Plant Pathologist.
C. S. Holton, Ph.D., Agent, U S. D. A.[2]
Grover Burnett, Ph.D., Research Assistant.

Poultry Husbandry

John S. Carver, B.S., Poultry Husbandman in Charge.
Donald Brazie, M.S., Asst. Poultry Husbandman.

Veterinary Science

J. W. Kalkus, D.V.S., Veterinarian in Charge, Western Wash. Exp. Station, Puyallup.
C. E. Sawyer, D.V.S., Research Veterinarian, Western Wash. Exp. Station, Puyallup

Branch Stations

H. M. Wanser, M.S., Supt. Adams Branch Station, Lind.
H. P. Singleton, M.S., Superintendent, Irrigation Branch Station, Prosser.
D. J. Crowley B.S., Specialist in Cranberry Investigations, Cranberry Investigations Laboratory, Long Beach.

Pacific Northwest Soil Erosion Station[2]

W. A. Rockie, B.S., Superintendent.
P. C. McGrew, B.S., Agricultural Engineer.
Arthur J. Johnson, Agent.

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[1] In cooperation with the State Committee on the Relation of Electricity to Agriculture.
[2] In cooperation with the United States Department of Agriculture.
[3] On leave.

trials. The best stands have been obtained from very early spring sowings although volunteer plants appearing in mice caches have indicated stands should be obtainable from fall seeding. The seed of Quincy grass has so much lint covering that when harvested from the field it balls up and cannot easily be handled by seeding machinery

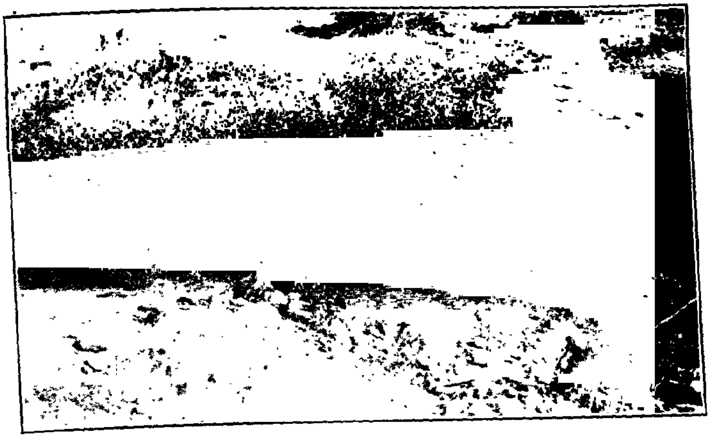

Figure 12. Quincy grass (Oryzopsis hymenoides) June 25, 1929. A few scattering plants were obtained on this plat from spring sowing on fallow in 1928. The plants were much more thrifty in 1929 when two years old than they had been the first year.

until delinted. The seed also has a very hard shell. It is a bunch grass and in pure stands does not furnish a complete coverage of the soil. It does not grow so early in the spring as crested wheat grass and requires two years before the roots develop sufficiently to withstand pulling by grazing stock. Stands of Quincy grass are shown in Figure 12 and Figure 8. It seems best adapted to very coarse sandy lands and waste places where the soil has been considered too sandy for wheat culture.

Perennial rye has not been tried very extensively on the Station but seems to have more promise than many other grasses. It grows at cool temperatures, but is not as winter hardy as crested wheat grass. It seems to have quite thrifty seedling plant characteristics and seed that can be handled easily in seeding machines.

Summary

An introductory discussion has shown the importance of forage crops in central Washington and some of the difficulties in producing harvestable forage.

The Adams Branch Station was established at Lind in 1915 in order that agronomic problems of central Washington might be solved.

Climatic data show an average annual rainfall of 7.88 inches, an effective growing season rainfall of 1.19 inches, and that seasons favorable for fall or prolonged spring seeding occur about once in five.

The growing season starts with the spring thaws and ends when soil moisture is exhausted in midsummer. For early spring-sown plants it is 104 days long and the first 45 are subject to frost.

The small grain cereals are recommended for producing harvestable forage. When winter wheat and rye cannot be grown, spring wheat should be sown.

Field peas and hairy vetch are the most desirable annual legumes

Most of the miscellaneous forage crops tried were unsuccessful

Alfalfa and sweet clover are not recommended because yields have been poor and stands hard to obtain.

Crested wheat grass which has been grown on the Station for 14 years has been the most promising grass tried. It is winter hardy, starts growth very early in the spring, the stands persist for long periods, and it is well liked by stock. It can be sown with an ordinary grain drill and is recommended for lands on which wheat culture has been discontinued.

Quincy grass is recommended for coarse sandy lands.